Designing an interactive olfactory robot for and with dogs

Master's Thesis

Shreyasi Kar

2019

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New Media Design and Production
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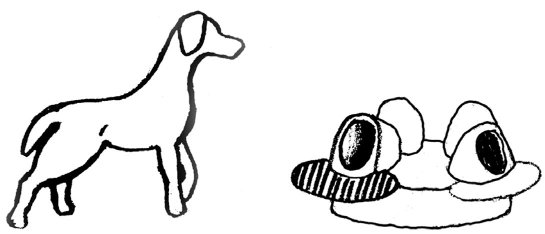

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Master of Arts thesis abstract

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Title of thesis Designing an interactive olfactory robot for and with dogs

Department Media

Degree programme New media design and production

Year 2019 **Number of pages** 83+1 **Language** English

Abstract

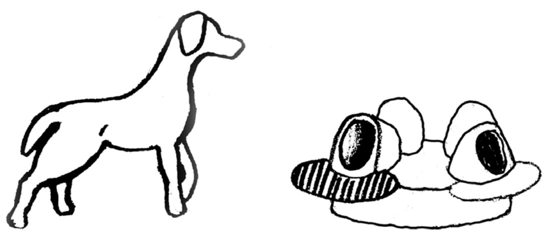
This thesis follows the development of Scent Bot, a smell-based enrichment and training device ecosystem for dogs. The device is designed for dogs to use independently. The sponsor of the project, Nose Academy Oy, gave the design brief.

Through the choices made while developing the device, a dog-centric design approach emerges, which is discussed at length. Challenges such as those of linguistics and cognition that arise when designing for another species are mitigated through an iterative, multispecies participatory design process. In addition to differences in comprehension, differences in physiology, and ways of experiencing the world are key elements taken into consideration while designing. The interactions of the dog with the device are based on methods coming from ethology and animal training. The interactions were then tested with dogs and revised based on the test results in an iterative looping manner.

The design method used in this thesis forwards the conversation around the involvement of animals in the design process while designing for animal-computer interactions. Such design methods can also be used to understand what participatory design can mean where user groups cannot give direct verbal feedback to the designers such as young children and others who are differently abled.

The product finds use both in research related to canine olfaction and commercial applications. If launched now, Scent Bot will be the first commercially available automated olfaction-based interactive enrichment device for dogs in the world.

Keywords dog-centric design, interspecies participatory design, olfactory enrichment device, canine robot



ACKNOWLEDGEMENTS

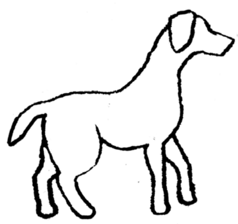
For Zoe, Trixy and Milo.

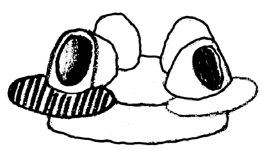
Now, that this difficult document is made, here is a toast to those who made it possible. To Nala, Lyra, Kössi, Lucky and Tyyppi for making user testing sessions warm and stress relieving. To Anna and Susanna for doing the amazing work you do, for your patience and, for always being open to all the crazy ideas we wanted to try. To team Nose Knows.

To Ilyena, for all the help, feedback and ideas about putting my thoughts to paper. To Matti, for not just being my thesis advisor but for all the support and mentoring for the last two years at Aalto. To my Design Factory community, for all the creative ways to say yes. Especially to Eetu, Floris, Joel, Marthe and Martti for all your encouragement and support.

To Ma, Babai and Didi for always being there for me, no matter what I am up to. To Riku, do not worry, I know where to send the cheque. Also, thank you for the illustrations. To Reishabh, we did it. To Saudamini, Paru, Pooja, Nayantara and Diu for being my moos.

Lastly, to everyone on two legs and four who were involved with this project. It is what it is.





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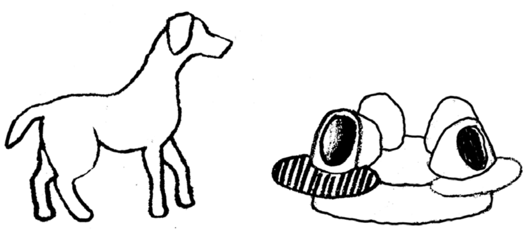

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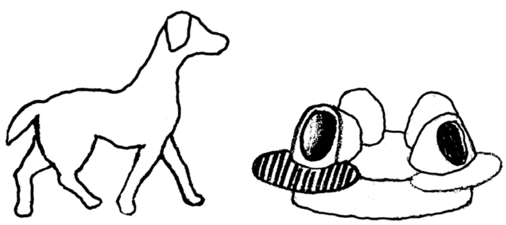
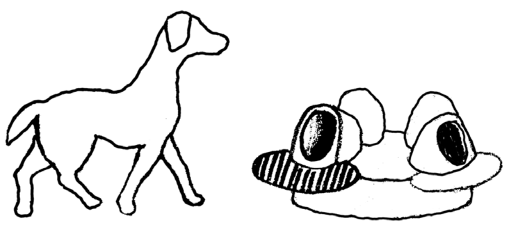


Chapter 1

Introduction

This chapter introduces the context of the thesis, gives an overview of the structure of the thesis and highlights the motivation behing the topic of the thesis.



1.1 Introduction to thesis

The focus of the thesis is on the product development journey, and the design process followed while developing Scent Bot, an olfaction-based enrichment device for pet dogs. The device can also be used for training dogs professionally for smell related tasks such as drug detection, scent tracking, and medical detection. Scent Bot is a device ecosystem that consists of three parts. First is a device called scentBot; second is the treatDispenser and, third is a mobile application.

The literature review of this thesis highlights conversations from the field of Animal Computer Interaction (ACI) around the involvement of dogs in the development of technology for them. Furthermore, it discusses how core concepts from user-centered design can be applied and understood from the perspective of a canine user. Lastly, it discusses currently available enrichment devices for pet dogs.

The thesis has been supported by Aalto Design Factory, Aalto University and, Nose Academy Oy from Finland. A part of this thesis was done during the Product Development Project (PDP) at Design Factory in the academic year 2018-2019, where Nose Academy was a sponsor. The design brief was provided by the sponsor and an interdisciplinary team of students called Nose Knows worked on it.

The team consisted of 11 students, six from Aalto University in Helsinki, Finland and five from Yonsei University in Seoul, South Korea. The team members were Shreyasi Kar (project manager), Alexander Franquelin, Kaustubh Patade, Yunfei Xue, Jaakko Lehtilä, Weiyu Tu in Helsinki and Juyeon Choi, Wonghee Park, Jinyoung Kim, Jihye Jang and Jisoo Lee in Seoul.

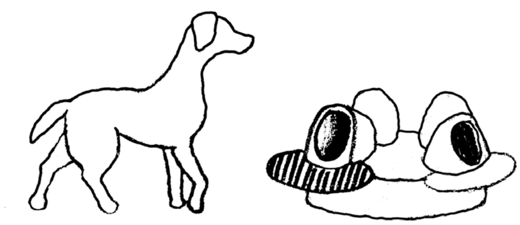
The project manager of the team is the author of this thesis. Along with all the management tasks, she was responsible for the framework for the design process, interaction design and electronics of the project.

After the PDP project, she has solely worked on the development of Scent Bot to its current state. The team is bound by a non-disclosure agreement with Nose Academy because of which it is not possible to share some of the training pathways and technical details of the final product. If required, a separate technical appendix with those details can be provided if request by the thesis evaluators. A diagrammatic explanation of the working logic of the device shall be provided during the thesis presentation.

Structure of thesis

Chapter 1 - Introduction Chapter 2 - Methodological Approach and Research Questions Chapter 3 - Literature Review	Introduce the context and scope of the thesis and looks into the past and current re-search around the topic. The research method is described.
Chapter 4 - Unpacking the design brief Chapter 5 - Dog centric iterative design process Chapter 6 - Suggestions for future development of Scent Bot	State the design needs and describe the process. Reflect on the challenges faced and how they were mitigated.
Chapter 7 - Discussion Chapter 8 - Conclusion	Wrap up the thesis by tying the topic and process followed to the current conversations in the research field.

Figure 1. Structure of thesis by Shreyasi Kar (2019).



1.2 Motivation

1.2.1 Pet ownership today

Humans have had dogs as pets for over 14,500 years (Benecke, 1987). Dogs are known to improve the quality of human life on an everyday basis by providing emotional support, love and companionship, while being able to perform highly specialized tasks such as search and rescue operations, when trained for it. In a study done by Statista on pet ownership in the United States, 90% of the dog owners said that their 'life has become happier since they got a pet' (2017). In the year 2017, it was reported that there were 89.7 million households in the United States with pet dogs (APPA, 2017). In 2019, Europe had a total of 85.2 million pet dogs, with 900 thousand of them in the United Kingdom (FEDIAF, 2019). In Finland, there were 810 thousand pet dogs (FEDIAF, 2019). The same report also indicates that compared to previous years, the number of pet dogs is increasing in Europe.

In this long history of domestication, for the first time we are seeing humans spend so much on pet products, accessories, food and, experiences. The turnover of the pet-related products and services industry in Europe is estimated to be at 18.5 billion euros in 2018, a 2.5 billion euro increase compared to 2017 (FEDIAF, 2019). The status that pets had within families is also changing and contributing to humans spending more on them. The Economist reports in its June 22, 2019 article on pet ownership that "in emerging markets wealthy people are more likely than poorer people to describe pets as "beloved members of the family", as opposed to merely well-treated animals." Further on in the article is mentioned:

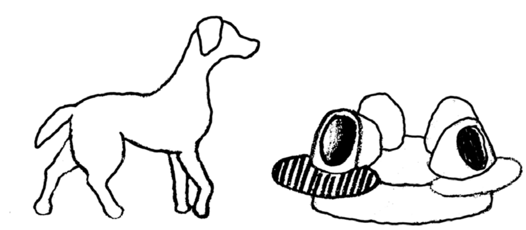
> Sami Tanner, the head of strategy at Musti Group, which owns almost 300 pet-supplies shops in Finland, Norway and Sweden, points to the Irish setters that his family has kept. In the late 1960s his mother's dog, Cimi, was fed cheap dog food and table scraps, and had just two accoutrements: a blanket and a leash. In 2009 Mr Tanner's dog Break became the first canine in the family to have his teeth brushed, and the first to

> acquire a raincoat and a bed. His current dog, Red, has several jackets, attends dog school, and is a model. (Pet-ownership is booming across the world, 2019)

The pet industry is responding to the changing status of pets by providing novelty pet commodities. In 2010, the Financial Times reported:

> At the leading edge of all this is what the pet industry calls “humanization”. The eternal tendency to see ourselves in animals has been commercialized into an awesome array of human-like goods and services for pets: from counselling for cats to motion-sickness pills for dogs, vitamin-enriched food to health insurance. People in all corners of the pet care industry describe a shift in attitude from “ownership” to “parenting”, from “pets” to “companion animals”, as domesticated wildlife becomes ever more involved in our lives.
>
> To its apologists, humanization is a benevolent process in which pet owners are increasingly aware of the needs – from the nutritional to the psychological – of the animals in their care. It might not be intellectually accurate, but pets benefit from the attention, and we enjoy giving it. Humanization also speaks to an era of smaller families, single-person households and ageing populations, in which pets are filling social and emotional vacancies formerly occupied by people. (Knight, 2010)

Based on the Consumer Technology Association's 2018 study on pet technology, it is reported that while the overall sales of pet products and services in the United States grew by 5%, sales in pet technology alone grew by 18% compared to 2017 and is estimated to have a revenue of $233 million (Raphael, 2018). Some of the commercially available pet technology products are discussed in the next chapter.



1.2.2 Dogs being left alone

While people are spending more in terms of money on their pets, the amount of time spent with pets is on the decline. In the UK for example, 25% of the dogs are left alone on a workday for more than five hours and another 48% left alone for anywhere between one to four hours a day (YouGov; People's Dispensary for Sick Animals, 2013). Similar reports pertaining to Finland were not available. Therefore, a quantitative survey was conducted for the Scent Bot project. The entire survey can be accessed in Appendix 1. For the question 'How many hours on an average does your dog spend alone on a work day', out of the 835 respondents, 67% of the dogs were left alone for over four hours, each workday (Figure 2).

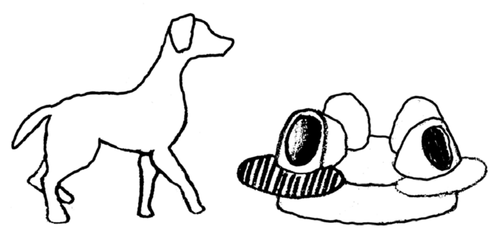
Figure 2. Pie chart showing the distribution of hours spent alone by dogs in Finland. From "Survey of your dog and you" by Nose Knows, (2018).

In Sweden, a telephone survey done by Norling and Keeling in 2010 found that 73% of the dogs are left alone while their owners are at work. While some workspaces do have provisions for the pet owners to bring their pets to work, these are very few and suitable for only certain kind of jobs leaving most of the owners with no option but to leave their pets behind at home.

The number of dogs being left alone at home is alarming and raises concerns for both the dogs and the owners. Dogs are reported to experience separation anxiety to varying degrees. Flannigan & Dodman (2001) define separation anxiety as "severe distress when an individual is distanced from other group members, but in canine behavioral terminology this term is most often restricted to dogs that become upset when separated from their owner" (p. 460). While the word upset seems mild, it can have very problematic manifestations. In the same report, the authors say that separation anxiety is one of the most common behavioral problem amongst dogs in the United States. Some of the behaviors expressed by the dogs when they are left alone are wreckage of furniture and other household items, howling or barking, defecation or urination even though they are housetrained and, injuring themselves. Also, there are more dogs with behavioral problems as while selecting dogs for breeding, often appearance is prioritized over behavior. Additionally, "Anthropomorphic selection – the search for soulful eyes, a lasting juvenile appearance and great, cartoonish paws – applies to behaviour as well, with dependent breeds favoured for guaranteeing an excited welcome at the end of the day" (Knight, 2010). Research by Rehn and Keeling found that even with dogs that do not exhibit separation anxiety, the long time spent alone without and physical or mental stimulation, can impact the wellbeing of dogs negatively (2010). In the survey conducted by Nose Knows (Appendix 1), when dog owners were asked what caused them the most amount of concern when the dogs were left alone, 34% said that it was the lack of entertainment for the dogs. 50% of the dog owners said their primary concern was separation anxiety or behaviors associated with it, such as destructive behavior or howling and barking.

1.2.3 Examination of human-dog interspecies relationship

The domesticated dog, as a species, has evolved to acquire a very unique position. Dogs are capable of providing for themselves and do not need any human intervention for survival. However, as pet dogs they are intertwined with the human mesh and while being capable of living independently, their daily existential activities like playing, eating, drinking, excreting are arranged by humans. They are almost an artificial species, specifically evolving to be better



understood by humans. Kaminski et al. (2019) observed that “Puppy dog eyes”, a common facial expression exhibited by dogs that makes humans sympathetic and want to nurture them, is actually an evolved trait. While evolving from wolves, dogs have developed a set of muscles which enable eyebrow movement which enable them to make such expressions. In this evolution process, they have also learned to understand human gestures such as pointing and following gazes that species closest to humans, chimpanzees, cannot. In the same paper, the authors cite research by Miklósi et al. (2003) and Marshall-Pescini et al. (2017) that shows, dogs establish of eye contact with humans when they are unsure or are seeking help. This is unique to the dog-human interspecies communication (2019).

Having these unique interspecies communication channels makes dogs an excellent candidate to be tasked with jobs that they can be trained for. Historically they were trained to use their sharp senses or agile responses to hunt, herd or guard. Today, dogs are used for very specialized jobs like detecting presence of diseases by smelling biological samples (Kasstan et al., 2019; Cornu et al. 2011), animal conservation and, prevention of illegal smuggling (Browne et al. 2006).

1.2.4 Canine smell behavior

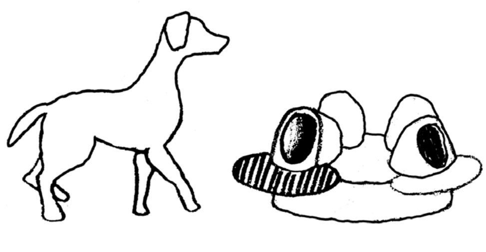
The majority of the jobs that a dog is tasked with involve their keen sense of smell. Correa (2011) writes that olfaction is the primary sense a dog uses for exploring its environment. Their sense of smell is a thousand times superior than that of humans. They also have a specialized organ called the vomeronasal organ that detects pheromones or chemicals from other animals such as humans. They are able to focus and find target scents that they are trained to look for even in a mix of rich background scents (Furton, 2001).

In Finland, one of the organizations researching canine smell behavior is Nose Academy. It is an academic start-up that was started in 2016 by Anna Hielm-Björkman, a veterinarian and adjunct professor at University of Helsinki and Susanna Paavilainen, a dog trainer and an animal hotel owner, along with two others.

Dr. Hielm-Björkman leads the DogRisk research group at the faculty of veterinary medicine at the University of Helsinki. A part of the research done by Nose Academy and DogRisk is training dogs to detect renal, breast and prostate cancers from samples of human urine. McCulloch et al. (2006), demonstrated the ability of dogs to detect lung and breast cancer from breath samples. Research done by other research groups indicate towards canine abilities of detecting cancer, malaria and, other illnesses through smelling volatile organic compounds (Taverna Gianluigi et al., 2015; Guest et al., 2019). However, research towards diagnosis of diseases by dogs also indicate towards limitations in accuracy of diagnosis (Dorman et al., 2017). Some of the limiting factors hindering the accuracy are current methods of training the dogs, trainer biases, interpretation of the dog signals, storage of samples (Gordon et al., 2008 & Jezierski et al., 2015). Mancini et al. (2015) demonstrate how using an animal computer interface helps overcome some of these limitations. This will be discussed in the Chapter 2.

While training the dogs for their research, Dr. Hielm-Björkman and Ms. Paavilainen observed that intense olfaction activity had a calming and tiring effect on the dogs and after the sessions, the dogs would either rest or sleep. Similar effects have been reported by dog handlers of dogs doing other types of scent-based detection tasks (Mächler, 1995; Ju et al., 2007). Unfortunately, in studies about canine olfaction, this calming effect of olfaction-based activity has not been actively researched and there is very limited research available on it.

Nosework (also known as K9 nose work) is a task-based scent detection activity, designed for dogs not engaged in professional scent training. In the training, dogs are taught to search for certain odors and locate the source. The target odors used are birch, clove or anise (“What is K9 nose work”, n.d.). In Finland, for example Nose Academy uses lavender, eucalyptus and laurel. The training method uses positive reinforcement where the dog is rewarded when it



finds the source. Ms. Paavilainen observed that initiating nosework training with rescues dogs that she was fostering, reduced their hostility towards humans.

In a study testing cognitive bias in dogs, it was found that dogs practicing nosework were more optimistic than the control group that was practicing heelwork. Heel work is training a dog to heel (The free dictionary, n.d.). For the study, one group of dogs was trained with nosework and another with heelwork for two weeks. The dogs were then introduced to an unfamiliar object, an empty ambiguous bowl. The time the dogs took to approach the bowl was measured. Here, the dogs that had lesser latency in approaching the bowl were said to be more optimistic. One of the factors that this result is attributed to is that the sense of smell is the most important sense for a dog and olfactory foraging is intrinsically rewarding for dogs. It is said “a practical recommendation from this experimental result would be to encourage owners to increase their pet dog’s foraging time through nosework or any other activity, such as natural sniffing during walks” (Duranton & Horowitz, 2019, p. 5).

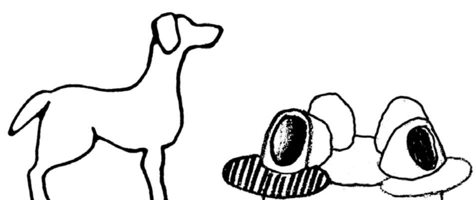
From the above it can be concluded that an enrichment device for dogs that are left alone at home, that utilizes the dogs olfactory foraging tendencies, could help in keeping them calm and improve their behavior. This hypothesis was the primary motivation behind the design brief given by Nose Academy. The secondary motivation was that such a device could also be used in their cancer detection research to eliminate errors in the signaling between the dogs and humans.

Chapter 2

Methodological Approach

& Research Questions

This chapter discuss the research methodology used in the thesis. It also lists the research question and frames it within the design brief.



Methodology

This thesis follows a practice-led research approach. According to Sheridan (2019) ". . . practice-led research is a conceptual framework that allows a researcher to incorporate their creative practice, creative methods and creative output into the research design and as a part of the research output." Haseman (2006) expresses that practice-led research enables the researchers to go beyond the traditional paradigms of qualitative or quantitative research which are dependent on the definition of problem statements or defined research questions. Practice-led research allows researchers to work with larger agendas while creating room for "experiential starting points from which practice follows" (p. 100). This method of research is particularly suitable for content creation and production as well as processes involving prototyping or iterative development (Haseman, 2006).

This method of research is the most suitable for this thesis. It allows room to report the learning from an iterative design process followed while following a design brief. The methods followed while designing the prototype inform the practice. The creative process is framed within achieving the goals of the design brief while questioning the methods used to design.

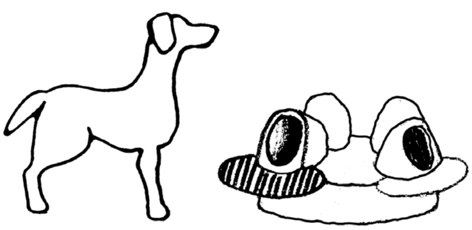
Brief - **Design an olfaction-based enrichment device for dogs which can be used by them independently.**

Research Question - **How can a dog participate in the process of designing interactive technology for them?**

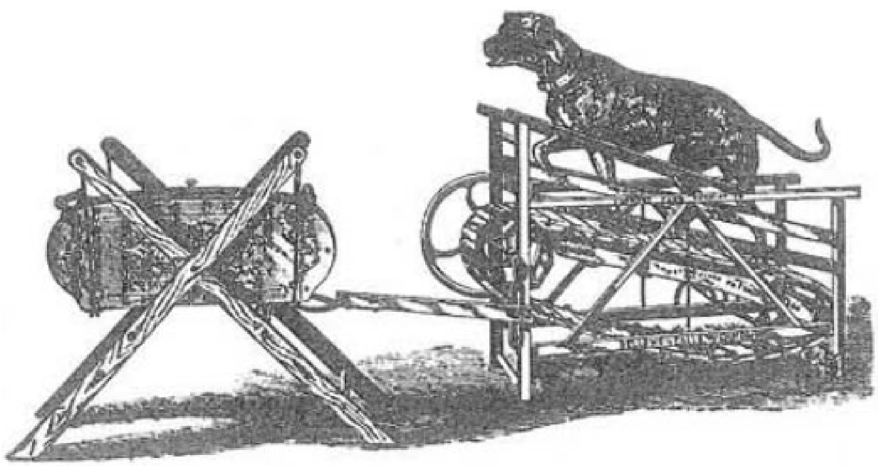
Chapter 3

Literature Review

This chapter discusses the current market for technological products for dogs, the emergence of animal-centric design situated within Animal Computer Interaction (ACI). It reviews two works of dog-computer interaction are most relevant to this thesis.



Technological products are rapidly evolving to be designed for non-human animal users (hereon referred to as animals). Animals use many different kinds of technologies in many different situations. Technology here means “a manner of accomplishing a task especially using technical processes, methods, or knowledge” (Merriam-Webster, n.d.). While not falling in the same category as todays technological products, one of the earliest machines designed to have been used by a dog is the turnspit or a butter churner (Figure 3).



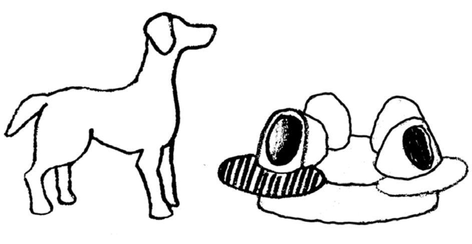
Rover, and other churn dogs like him, ran on a treadmill that operated a butter churn. The churn pictured above was a swing churn.

Figure 3. Dog using a butter churner. From “Dog power,” n.d., http://alloveralbany.com/archive/2016/11/07/dog-power. Copyright 2002 Hanford Mills Museum.

While these were designed to be used by dogs, it certainly was not for their benefit. The dog used the machine out of fear and not by choice. The dog would be placed on a treadmill-like device which is at an upward incline. Once the brake was let loose, the dog would keep running on the treadmill out of fear of falling down. The treadmill was connected to a churner where butter would get made as the dog moved. With the evolving status of dogs as pets as discussed in Chapter 1, technology for them has evolved responsively. Based on a review on barkytech, today, there are multiple devices available for dog owners to remotely interact with their pet dogs while they are away. Sophisticated wearables like activity trackers monitor the health of the dog and suggest customized diet and exercise plans to dog owners to boost the health of their dogs. The Disco Dog vest brings together fashion and technology for dogs in a wearable coat fitted with an array of LED lights for dogs that can be programmed to display messages, advertisements or different light patterns. The vest also displays a 'lost' message if the dog moves beyond a certain distance from the owner. With pet dogs increasingly spending more time alone in the confinement of their homes, there are a lot of smart pet toys entering the market ("barkytech", n.d.). Table 1 below lists some of these new interactive toys for dogs ("petqwerks", n.d.; "snuggle puppy", n.d.; "wickedbone", n.d.; "12 Best Interactive Dog Toys in 2019", n.d.).

No.	Name	Description
1	CleverPet	Designed as a gaming console for dogs, there are three touchpads that light up. If the dog touches the touch pad which lights up, it receives a treat. As training progresses, the device presents the dog with sequences of flashing lights which it must repeat to earn a treat. The owner is connected to the device through an app which tracks the progress that the dog is making with the puzzles.
2	VARRAM Pet Fitness Robot	Aimed at providing entertainment and exercising dogs and cats while they are left alone at home, the robot rolls around on the floor to make the pet move and dispenses treats as it moves. Play time can be scheduled using the app by the pet owner. The robot also has a speaker which is connected to the app and the owner can speak to their dogs remotely.
3	iFetch Ball Launcher	The dog (or human) drops a ball into the device which then shoots the ball for fetching.
4	Trixie Dog Activity Memory Trainer 2.0	The dog pushes a movable remote-control pedal to release a treat from the treat dispenser. The pedal can be moved or hidden in different places.

(Table 1 continues to next page.)



5	Wickedbone Smart bone	Bone-shaped robotic device that reacts to touches in different predefined ways and can be programmed to roll around on its own. It entices the dog to play with it by moving around on its own. An "emotional system" reacts to different emotions of the dog. The motion of the bone is also controllable remotely through the app.
6	Blinky Babble Ball	Babble ball makes sounds and blinks when touched and moved around by the dog.
7	SmartPetLove Snuggle Puppy	Snuggle puppy has been around for 22 years and is one of the oldest dog tech products on the market. A soft toy "puppy" with an artificial heartbeat eases anxiety when put in contact with the dog. An additional disposable heat pack can be added to the snuggle puppy to further comfort the dog.

Table 1.

While animals have been using technological products for a while, with the introduction of the field of Animal Computer Interaction (ACI) the emphasis is placed to really understand design from the view-point of the animal. Similar to user-centric design approaches that are advocated for in the field of Human Computer Interaction (HCI), ACI encourages development of interactions for animals to be informed by the animals' choices and requirements (Mancini, 2011).

Within the narrow field of Dog Computer Interaction (DCI) within ACI, there have been several different approaches taken to include dogs to varying degrees in the design process.

The category of dog wearables requires little to no active involvement of dogs in the design process of creating them. Similar to fitness trackers such as the Fitbit or Moov used by humans, the dog trackers are small devices that can be worn by the dog in its collar and does not require any active interaction from the dog. It monitors the dog's health by tracking everyday activities like sleep, walk, run and, play using tri-axial accelerometers. Some advanced trackers also track the location of the dog via global positioning system and monitor heartrate, respiration rate and body temperature. The data is collected from the dogs and transferred to the pet owner through Bluetooth or WiFi to a mobile app where it is analyzed and stored. Currently there are over 22 commercially available pet trackers. Companies focused on human health and navigation like Garmin are also entering the market ("Trackers," n.d.).

On the other end of the spectrum of involvement, Mancini et al. (2015) designed a canine interface for cancer detection dogs where dogs were active participants in the design process. Expanding upon the concept of participatory design processes with humans, their design process involved all the stakeholders, including the dogs as participants in the design process. This project is especially relevant for this thesis as it discusses the design of a signaling interface for medical detection dogs working with cancer detection. In their research, the dogs detect cancer in the biological samples presented to them by using olfaction. When they suspect the presence of volatile organic compounds associated with cancer in the samples, they signal to their trainers. If they signaled at the correct sample, the trainer gives a reward. The signal given is usually a trained behavior like sitting down or laying in front of the sample. The researchers observed that sometimes, the dogs were behaving according to a learned behavior which is not in sync with their natural responses. This causes a delay in indicating a correct sample and was a cognitive load for the dogs. Also, the given signaling mechanisms allows for the dog to only express 'yes' or 'no' to the samples that are presented with. When recordings of the training sessions were analyzed, the researchers found the dogs express varying degrees of interest in different samples. The signaling mechanism currently did not have any room for expressing this behavior. It was also observed that dogs take more interest and exert more pressure on the plates holding the samples (Figure 4) which they thought contained compounds associated with cancer.

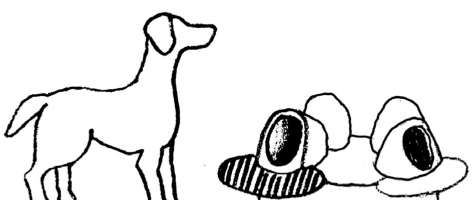


Figure 4. Cancer detection rig used in the research. From Re-Centering Multispecies Practices: A Canine Interface for Cancer Detection Dogs, Mancini et al. (2015). Copyright 2015 The Open University.

The final design of the dog-computer interface in question builds on this natural expression of the dogs and calculates a positive or negative response by measuring the pressure that the dog exerts on the plate containing the sample while sniffing. Mancini et al. (2015) call this ‘honest signaling’ and say that it “avoids having to negotiate a difficult interspecies communication gap” (p. 8). The focus of their design process shifted from designing for a behavior that was taught to the dogs to bridge a communication gap with humans, to allow for natural expression where the interface did the interpretation and handled the signaling to the humans.

The need for honest signaling methods also exists in other fields of research within ACI. Studies by Williams et al. (2011) centered on understanding how the sense of sight works in dogs. They relied on studying behaviors of visual cognition using a wearable head mounted eye tracking device. Commenting on this research, Hirskyj-Douglas et al. (2018) observe “Animals can be trained to use tracking systems [112] or can be tracked wearing head-mounted systems [110], but both these strategies are known to influence their ordinary behavior, which is the very thing, ironically in these studies, that researchers are typically aiming to measure” (p. 16).

From other research projects it has been seen that dogs can be trained to use different interfaces such as touch screens to dial the emergency number 911 (Zeagler et al., 2016), operate buttons to open and close doors as mobility assistance dogs (Mancini et al., 2016) and activate wearable sensors on their vests on command to be used in different situations such as search and rescue (Jackson et al., 2015).

On the topic of design of interfaces for use by a dog, in his thesis work Rover@Home (2001), Resner describes the process of designing a remote interaction system between dogs and humans (Figure 5). The dog is given a task, which is to touch an alley-oop. Upon successful completion of the task, the dog is rewarded with a click and an edible treat. The human user can speak to the dog through the internet and can give commands or praises through sound.

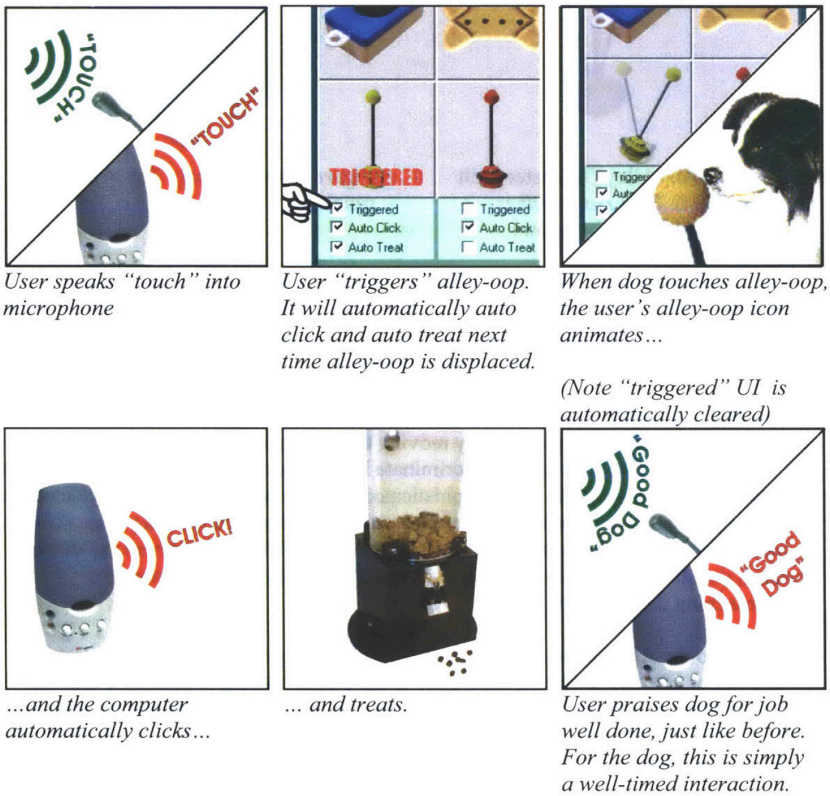
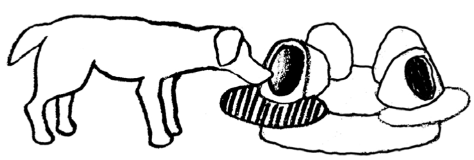


Figure 5. Diagram explaining interaction system of Rover@Home. From Rover@Home: Computer Mediated Remote Interaction Between Humans and Dogs, Benjamin Resner, 2001

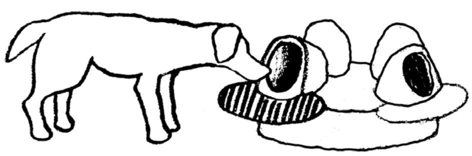


In his thesis, Resner (2001) discusses user-centered design principles by Norman & Draper (1986), applied in a non-human animal user context. These principles are well suited for understanding the design approach in this thesis. Resner talks about the roles of task domains, affordances, cognitive modelling and direct manipulation in designing interactions for animals. There needs to be a clear understanding of what behavior of the animal is being designed for or, will be utilized in the interactions. The animal should desire the outcome of the interaction as that can help overcome slight deficiencies of the interaction. The chances of a successful interaction increase if it is designed for a clear distinct use. "Affordances are especially relevant to animals because, like many humans, animals do not read manuals" (Resner, 2001, p.18). Understanding affordances as the elements of interaction, how to use the device should be understood from its design. The interaction should be intuitive and not be dependent on the user memorizing it. While animals might require exercises in getting started with the device, if the interaction is designed keeping the animals' natural tendencies in mind, it makes it a lot easier to use it. Interfaces should allow for animals to interact with them through actions that they are trained to express or do instinctively. The interfaces need to be simple and be designed to be understood by the animals, free of abstractions.

Chapter 4

Unpacking the Design Brief

This chapter details the needs of the prototype that had to be developed. The structure and system architecture of Scent Bot is developed in this chapter.



Product Development Project (PDP) is a course run at Aalto Design Factory, Aalto University, Finland. The focus of the course since has been to tackle real-world problems in interdisciplinary, international student teams. Each team typically consists of 8 to 12 students, with one student as the Project manager. About half of the students are from Aalto University and are based in Finland and the other half collaborate remotely from various different partner universities across the globe. Each team receives an open-ended design challenge from a sponsoring company, which they must work on for the duration of the whole academic year (September - May; nine months). The budget that each team works with was 10,000 euros in the year 2018-2019. 7,500 euros is allocated to prototyping and the remainder to cover travel expenses. At the beginning of the course, lectures and specific training sessions for different aspects of product development such as prototyping, electronics, project management are provided. However, the focus of the course is on hands-on prototyping (Rautavaara et al., 2014). The students are encouraged to learn through experimenting, building, failing and revising. In that sense, students decide their own design pathway and the learning experience is unique to each team and relevant to the project they work on. Having the PDP course as a setting for the development of the Scent Bot aided in the development of the user centric design approach.
Nose Academy was a sponsor for the PDP course in the year 2018-2019. Figure 6 shows the design challenge given by the sponsor Nose Academy. The main goal was to “create a sniffer robot for dogs”.

Table 2 below states the requirements set for the device by the sponsor. SR stands for sponsor requirement.

Requirement number	**Details**
SR1	The dog should be able to use the device independently
SR2	The device should be not destructible by the dogs (dog-proof)
SR3	The dog owner should be able to view the training statistics of the dog
SR4	The device should have a programable start and stop

Table 2.

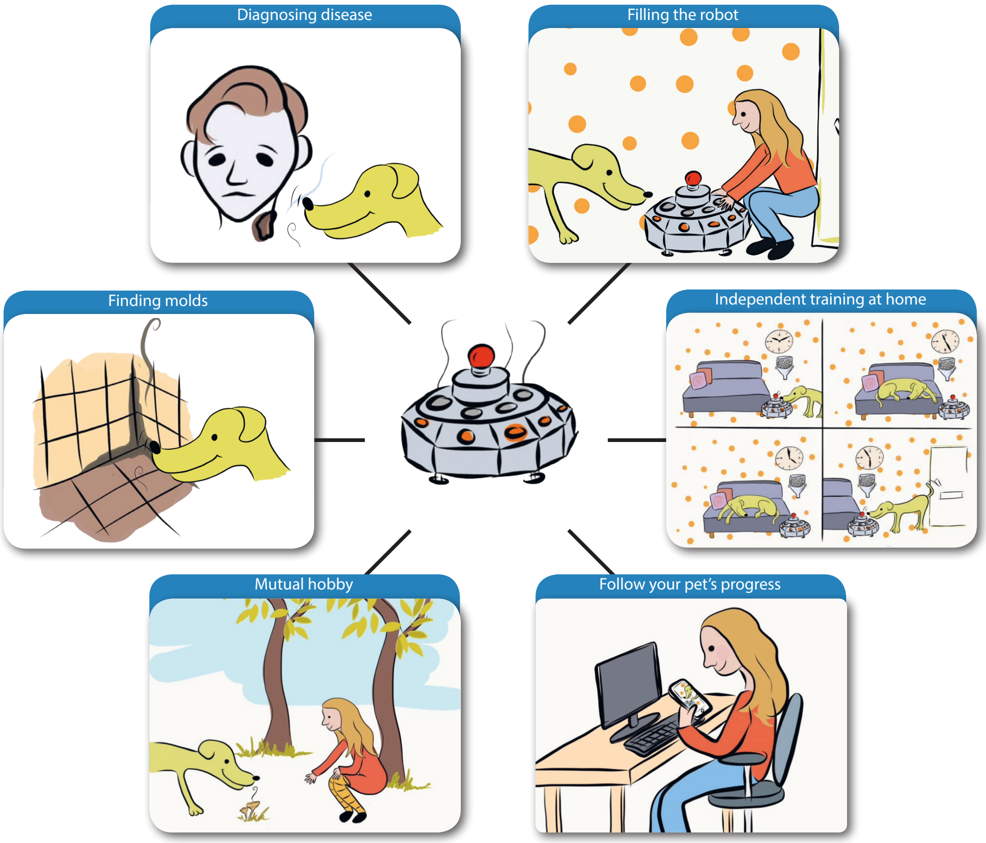
Create a sniffer-robot for dogs with Nose Academy Oy!

Nose
Academy

The most important sense of a dog is smell. Smelling stimulates the dog brain and working with smells calms the dog and strengthens the pet-human bond.

Nose academy is a Finnish academic start-up company that does research on the use of canine smell behavior. We are looking for a team that will create a ”Canine Sniffier Robot” for us and for other dog owners. Odor discrimination will be easy to teach to your pet dog if you have the robot!

Meet the challenge – together we can!



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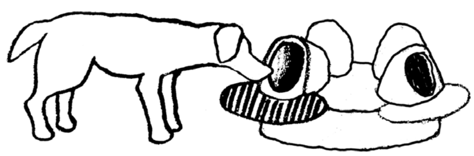
Susanna Paavilainen
044 504 4464
susanna.paavilainen@wisenose.fi

Figure 6. Design Brief by Nose Academy (2018).



The first step of the design process was to unpack the brief with the sponsor. The design brief required automation of various steps of the training process that they had been following at their research facility. For observing the training process, the team went to the sponsor's training facilities at Viikki, Helsinki. There were three setups being used to train the dogs. Figure 7 shows setup 1, Figure 8 shows setup 2 and, Figure 9 shows setup 3. All the three setups are designed to be used with stainless steel cans with the lid having a steel mesh found at IKEA. Each can holds one scent sample.

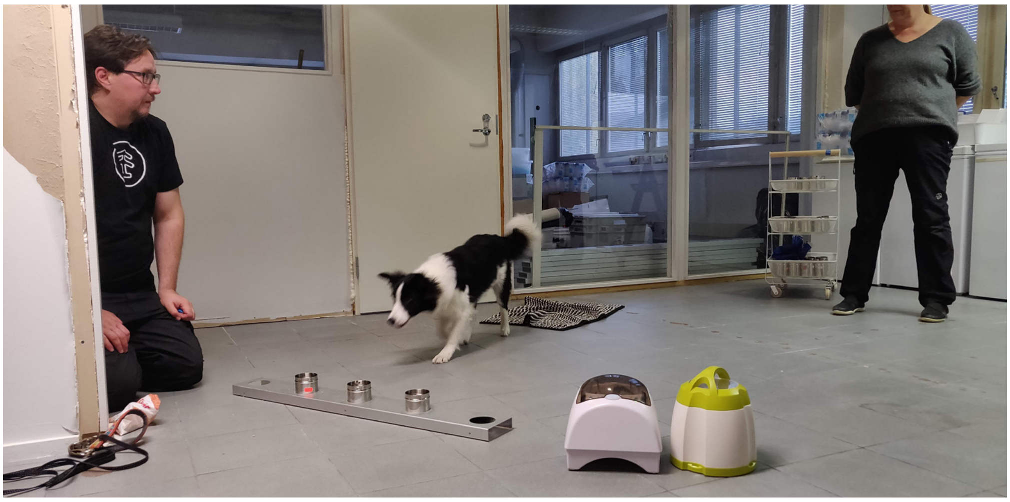


Figure 7. Setup 1 being used with Ami by Nose Knows (2018).

Figure 8. Setup 2 being used with Kössi by Nose Knows (2018).

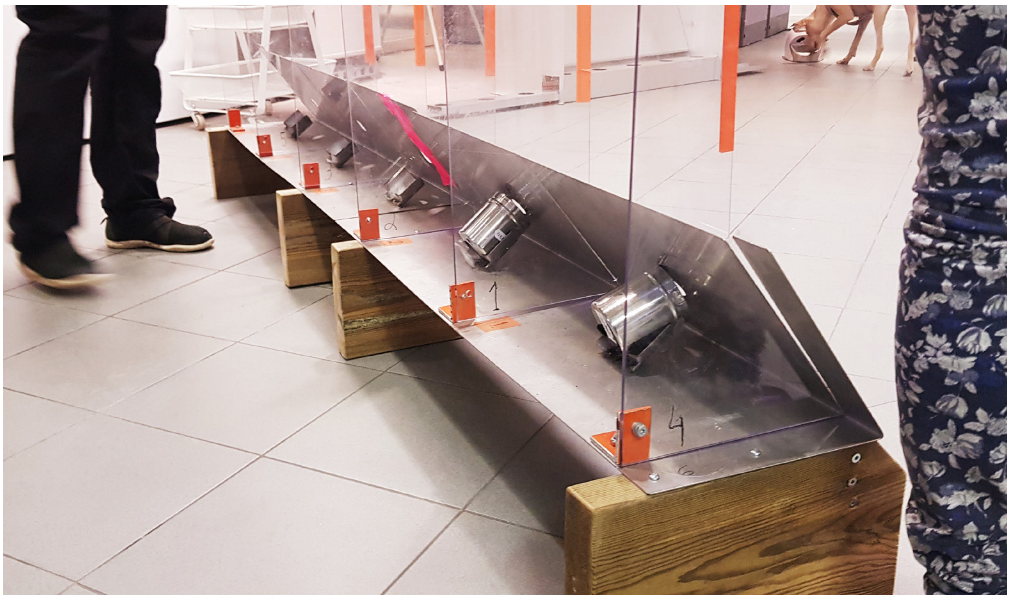
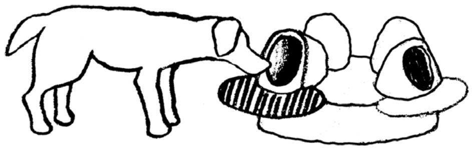


Figure 9. Setup 3 by Nose Knows (2018).

Setup 1 (Figure 7) – An aluminum metal sheet is bent to have a 'C' shaped cross section. The top plane is solid and has five equidistant circular holes for placing cans in them. A can with the target scent is placed with at least one more can. In between two attempts by the dog for finding the target scent, the cans are shuffled manually by the trainer or an associate.

Setup 2 (Figure 8) – A similar 'C' shaped aluminum track as setup 1 is placed inside an outer casing with holes with which the cans on the track align. The track can slide inside the casing. In between two attempts by the dog for finding the target scent, the track is slid manually by the trainer. The trainer and the dog are visually separated by an aluminum sheet. In this setup, the relative position of the cans does not change.

Setup 3 (Figure 9) – An aluminum sheet it bent at an angle of around 45 degrees. The plane which is at an angle has equidistant holes for the scent cans. The trainer stands behind the setup. The cans are placed from the back. Additionally, there are clear acrylic separators sectioning off each hole. In between two attempts by the dog for finding the target scent, the trainer manually changes the position of the can.



For all the three setups, the same positive reinforcement method was used for shaping the behavior. When the dog would correctly identify the target odor, they were rewarded with a click sound from the clicker. The trainer would also trigger the treat dispenser with a remote. The treat dispenser was kept at a distance from the tracks, and it gave a treat to the dog. Hereon, in this thesis rewarding the dog refers to the dog receiving a click sound and a treat. The sponsors demonstrated three training scenarios. They are summarized below.

i) **Scenario 1** – Ami, a five-month-old Border Collie was being trained by her owner, Ville Vihne. Ami was new to nosework and had only done two short sessions of training before. Her target scent was eucalyptus. For her training, setup 1 was being used. When Ami correctly nudged the can containing the eucalyptus scent with her nose, she was rewarded by the trainer.

ii) **Scenario 2** – Kössi, a seven-year-old rescued Spanish Galgo was being trained by his owner Ms. Paavilainen. Kössi has an extremely sensitive sense of smell and has undergone extensive nosework training. He was being trained on setup 1. His target odor was cancer in urine samples. He has undergone training for this target odor before. He would start searching for the target odor when Ms. Paavilainen would say ‘töihin’ which in Finnish means ‘go to work’. To identify the target odor, he would paw the track, near the can that he was sniffing. He was rewarded when he identified the correct can.

iii) **Scenario 3** – Kössi was being trained for tea as a target odor by Ms. Paavilainen. This was a new target odor for him. The first step was to familiarize Kössi to the new target odor. To do so, Ms. Paavilainen sat on a chair with a can in her hand which contained tea leaves. When Kössi brought his nose near the can and smelled it, she rewarded him. This process was repeated a few times. Then, the can containing the tea leaves was kept alongside an empty can on the floor. When Kössi indicated the can with the target odor by tapping it with his paw, he was rewarded. After repeating this a few times, setup two (Figure 8) was used. Kössi had trained on this setup before and was trained to signal by sitting down in front of hole that he thought contained the target odor. If the signal was correctly given, he was rewarded.

Some of the problems with the current training methods and devices used became apparent during the visit. Firstly, the treat dispensers would get jammed quite often. This seemed to be a problem occurring across different manufacturers of treat dispensers. Also, the beeping alert sound that the treat dispenser made when it got jammed would disrupt the training. Sometimes, the dogs would be pawing the treat dispenser roughly. Secondly, the cans had some stickers and others visual markers on them which helped the trainer know where the correct can was. Dogs can also learn to use this as a marker to indicate the correct can, making it ineffective for smell training. Thirdly, when the scent cans slide along a track, their relative position to each other doesn't change, i.e. the sequence of smells remains the same. Lastly, the click sound from the clicker should be delivered as soon as the dog performs the desired task to mark it. Delay from the trainer to click can be detrimental to the training.

Figure 10 shows the training process broken down into sequences of tasks. From the list of tasks, those which could be automated were identified.

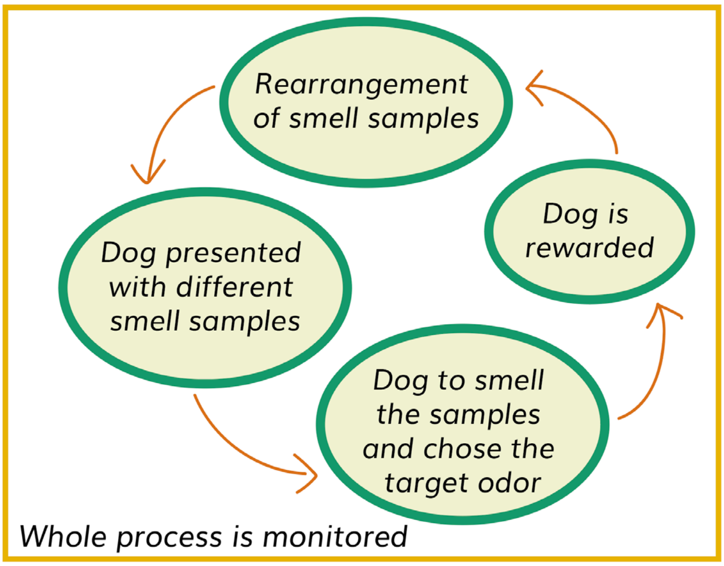
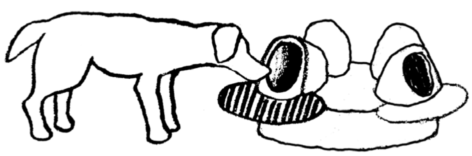


Figure 10. Diagram of training steps by Shreyasi Kar (2019).



The design brief mentioned only one device to be prototyped. Given the strong smell of dog treats, it was decided to keep the treat dispenser completely separate from the part that contains the odor samples for the dogs. This also helped meet SR2. The treat dispenser could be mounted at a height so that it was out of the reach of the dog. As this was an enrichment device to be used by dogs when they were left alone, to meet SR3 and SR4, a mobile application would give the pet owner a remote control over the system. It became clear that two devices would have to be made, one which had the smell samples – this came to be called scentBot. The other which dispenses treats is called treatDispenser. The third part is a mobile application (app). The whole system together is called Scent Bot.

Table 3 below describes the list of features for this three-part device ecosystem that the team came up with, categorized by each of the three parts.

scentBot	treatDispenser	Mobile application
Interaction element with dog	Separate from scentBot	Remote control of system
No contamination of different odor samples	Out of dog's reach	Training tips
Relative and absolute positions of individual scent cans to change	Treats cannot jam inside	Training progress
Dog-proof	Clicking sound	Profile of the dog
Scent cans washable and removeable	Camera	Stream from camera mounted on training device
Shutdown after programmed number of rounds	Sensing how many treats are left	Tinder/meetup socialization of dogs and owners
Easy to use for dog and humans		Police/customs/researchers to find trainable dogs
Parts should be easy to clean		Create part-time jobs for dogs

Table 3.

Based on the features mentioned in Table 3, the first step was to design a system architecture and choose a suitable cloud-based service which would store and communicate the data between the different devices. After an analysis and trials with some of the popular internet of things (IoT) platforms such as ifthisthen-that (iftttt.com), Kaa IoT platform (kaaproject.org), Thingspeak (thingspeak.com) and adafruit (ada-fruit.io), because of its ease of use, community support and wide scope of integration, adafruit.io was chosen. Figure 11 shows the system design of Scent Bot.

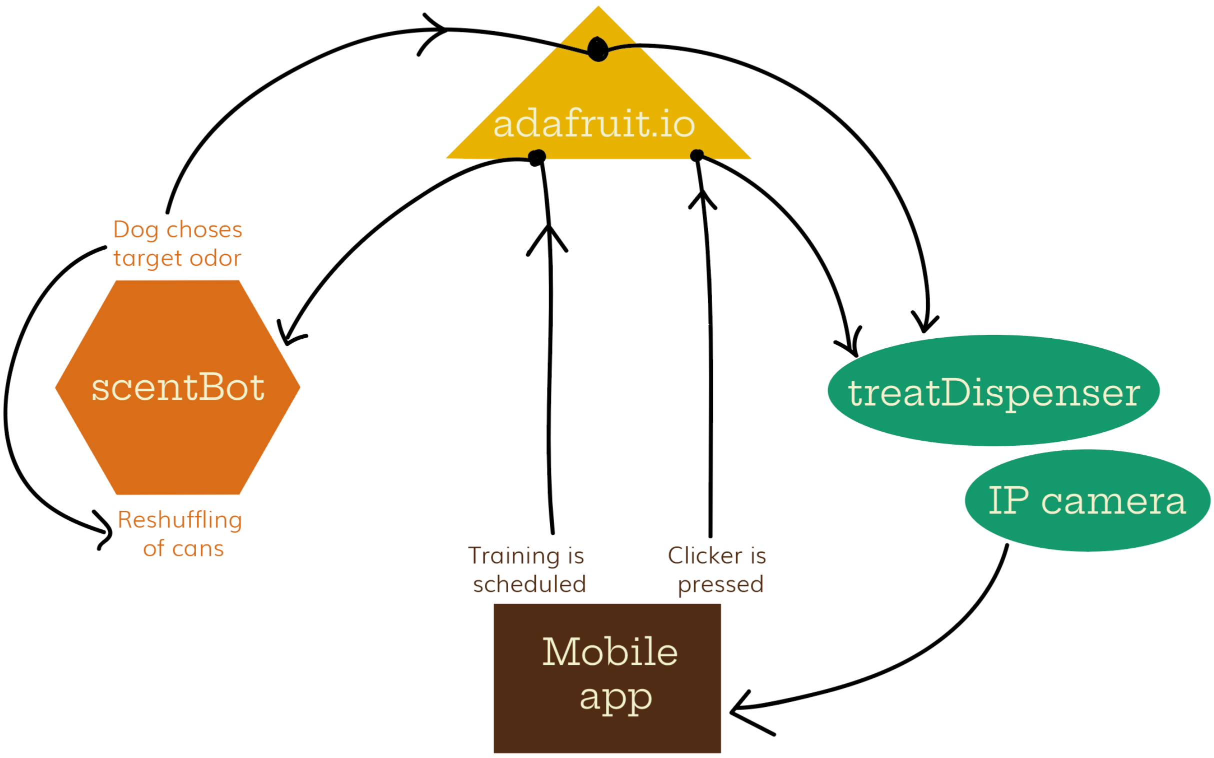
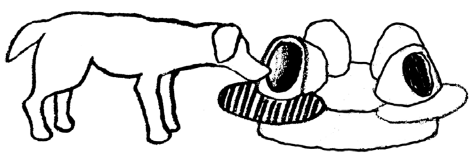


Figure 11. Basic system design of Scent Bot by Shreyasi Kar (2019).

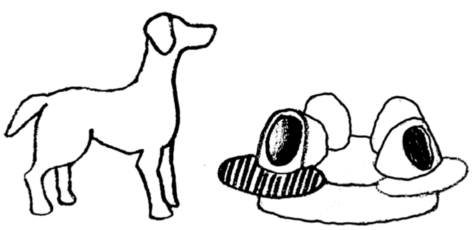


Chapter 5

Scent Bot

Design Process

The following chapter discusses the design process followed and the reasoning behind the design choices. It also shows how an iterative, participative design process was followed in a real-world product development scenario.



As mentioned in Chapter 2, to understand the current landscape of lifestyle of pets and their owners in Finland an online quantitative survey was carried out. There were no statistics available for data like time dogs spent alone in Finland or what the concerns of pet owners were when the dogs were left alone. These questions were asked in the survey. The entire survey can be accessed in Appendix 1. The questions in the survey were divided in the following four sections.

i) Section 1 – Questions about the dog and owner. This section contained questions related to the members of the household, age and breed of the dogs, time that the dogs were left alone for, parts of the house that the dog had access to when alone, the concerns with dogs being left alone, money spent on dogs and use of dog gadgets.

ii) Section 2 – Questions about the dogs’ training. This section contained questions related to how the dog was trained, who trained the dogs and for what, the time spent on training and the use of training aids.

iii) Section 3 – Questions about nosework (scent training). This section had questions related to familiarity with nosework and if the dog owners found it useful for their dogs to be trained for it.

iv) Section 4 – Questions related to pet-owners’ preferences in design of household gadgets. The questions in this section were presented as sets of images of existing devices from which they had to choose the one that appealed the most to them based on appearance alone.

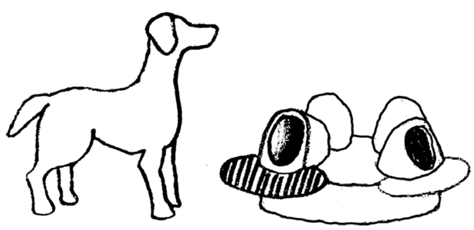
The survey had 835 respondents in Finland in February 2019.

5.1 Developing the scentBot

The primary function of the scentBot was to present the dog with the target odor and other smell samples and record the choice that the dog would make. It was thought that there could be two ways in which the samples could be presented to the dog. First would be that one by one, individually, different samples are presented and the dog indicates when the target odor is present. Second would be that there are multiple samples presented to the dog at the same time. One of those would be the target odor and the dog chooses it from the rest the samples.

The second method mimicked how dog experienced smells in nature and, was similar to the training method used at Nose Academy. Therefore, it was chosen as the mechanism for presenting the different odor samples to the dog.

During the visit to the sponsor’s training facility, it was observed that when different scent samples are presented to the dogs in a line, the dogs would either paw next to the can containing the target odor or sit down in front of it. When the arrangement is changed so that four cans were placed in a two by two grid, there is a possibility of confusion and misinterpretation of the dog’s signal. As explained in Figure 12, it is possible for the dog to smell sample number 2 while standing in front of sample number 1. In this scenario, when the dog signals upon finding the target odor, it will be in front of sample 1 and not sample 2. To eliminate errors such as this, there is the need for a hood, around the source of the smell.



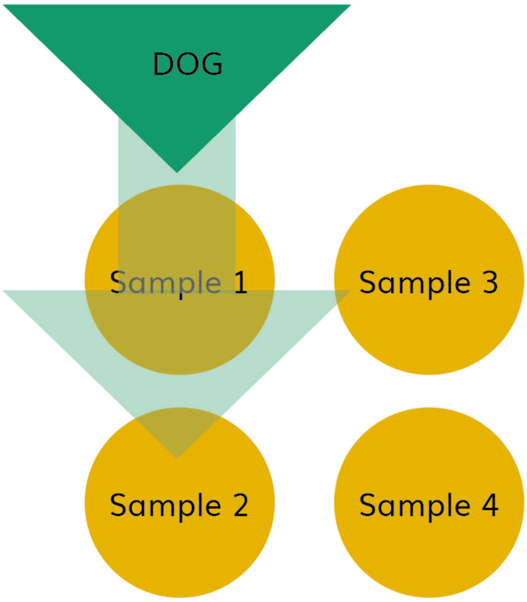


Figure 12. Possibilities of misinterpretation of signals when samples are presented in a 2 by 2 grid by Shreyasi Kar (2019).

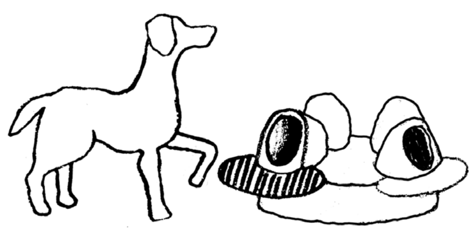
5.1.1 Iteration 1

Figure 13. scentBot iteration 1 by Nose Knows (2018).

The first iteration (Figure 13) for the scentBot was a cardboard prototype. The device was circular with three layers. The circular

shape was chosen arbitrarily. Layer 1 was the bottom and the base for the electronics and the motor would be placed at the center, with the motor shaft pointing upwards. Layer 2 was attached to the motor shaft in the middle and would rotate with the motor. This layer had additional three disks, which would rotate independently. Each disk had space to place two scent samples, making the machine capable of holding a total of six scent samples at the same time. Layer 3 was the top-most layer and had three holes for smelling the samples in layer 2. Layer 2 would align with layer 1 in a way so that out of the two scent samples on the disk, only one would align with the hole on layer 1. The hole was covered with a hood, to contain the smell. Layer 1 was also the layer that the dog would interact with.
After finishing the cardboard mock-up, it was presented to Edi, a six-month old Jack Russell Terrier belonging to one of the team members. Edi did not approach the prototype. Next, food was used as a motivator. Dog treats were hidden under the hoods. The opening of the hood was small for the size of Edis' snout. When left alone with the prototype, he bit the edge of the hood. Also, Edi moved away from the prototype when the stepper motor started. From this iteration, a new list of required dog-centric design features emerged. These dog requirements (hereon DR) are listed in Table 4 below. The failure of iteration 1 also highlighted the need for a systematic method of testing.

Before the next iteration, the team revisited the sponsor's training facilities to observe the training process and record it on video. These videos were done to study the trainer's commands and the gestures dogs made while finding the target odor and signaling when they had found the target odor. The nosework training used a scaffolded structure to shape the dog's behavior. A similar training method would need to be applied for getting the dogs to start using the device as well. Additionally, nosework training was started with Edi.



Requirement number	Details
DR1	Hood to accommodate snouts of different sizes and shapes while not retaining smells from previous samples
DR2	The shape of the hood should make it difficult for the dogs to bite it (Also relates to SR2)
DR3	Quiet motors
DR4	Appropriately timed auditory feedback

Table 4.

5.1.2 Shift towards a dog-centric iterative process

Moving forward, the device was broken down into parts and they were developed separately. Such a process allowed for rapid and agile development of the prototype. The iterations were tested with six dogs of different sizes, breeds (table 5) and levels of nosework training at Design Factory with the student team and the sponsors present. Then the parts were taken by the sponsors to their research facility and tested with other dogs of different sizes and they give feedback on the changes needed to the team which were then incorporated in the next iteration. Once the changes were incorporated, the design was again tested with the dogs and feedback collected and incorporated in the next version on the design.

5.1.3 Development of the hood

There were three designs of the hood made and 3D printed for testing with the dogs. The three hoods were arranged linearly and taped to an opaque piece of acrylic so that smell samples could be hidden under the hoods (Figure 14). The acrylic also had a hole under each hood for the smell to be accessible. The acrylic piece was at a clearance of 5 centimeters from the ground and supported by legs to allow for changing the place of scent samples under it.

Name	Age	Breed
Edi	6 months old	Jack Russell Terrier
Nala	6 months old	Mix
Lyra	3 years old	Mix
Tyyppi	7 years old	Golden Retriever
Lucky	7 years old	Golden Retriever
Kössi	7 years old	Spanish Galgo

Table 5.

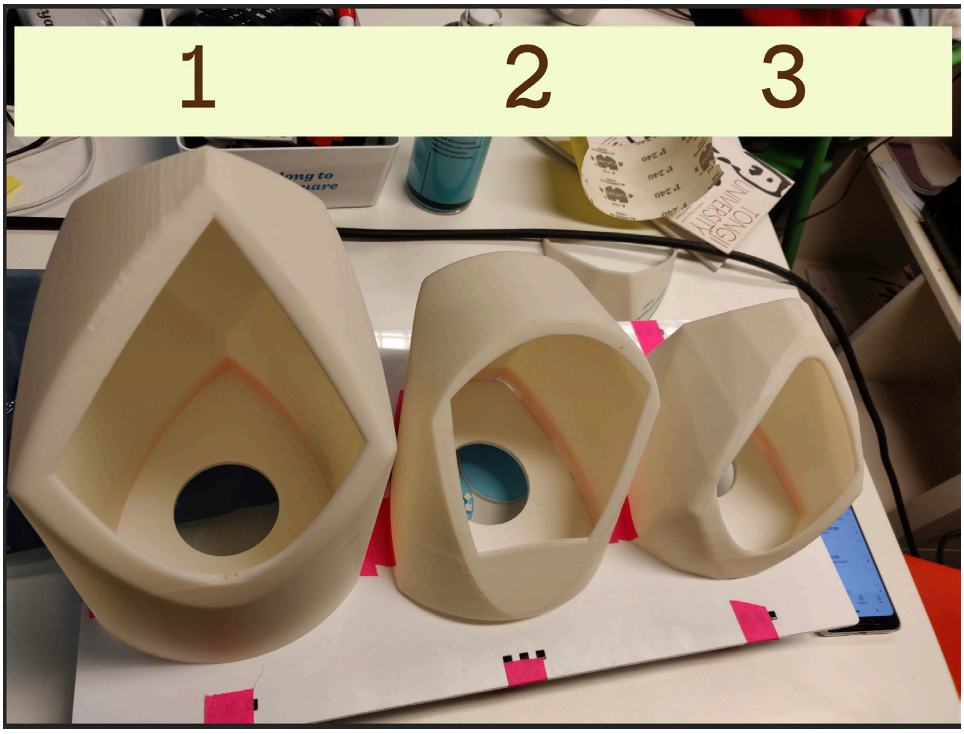
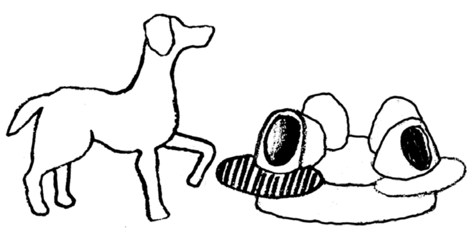


Figure 14. Initial hood designs by Nose Knows (2018).



The test was broken down into the following steps.

i) Familiarizing the dogs to the smell of eucalyptus, which was the target odor. The dog was presented with a sample of eucalyptus in a can and was rewarded when it brought its nose near the can to smell it. This exercise was repeated a few times.

ii) Finding the smell. The can was placed on the ground and the dog was rewarded when it brought its nose near it. The treat was given at a distance from the can. The position of the can was changed in the time that the dog took to retrieve its treat. This exercise was repeated a few times.

iii) The introduction of signing. Similar to the previous step, the can was placed on the ground and the dog was rewarded when it pawed the can or the ground next to it. The position of the can was changed while the dog was retrieving its treat. The time taken by the dog at each attempt to find the smell was noted. The duration of time recorded was from when the dog returned to search for the sample to when it signaled.

iv) Introduction of the hoods. The test apparatus with the three hoods (Figure 15) was placed on the floor. The can was then hidden under one of the three hoods. When the dog found it and signed, it was rewarded. The position of the can was changed to another hood while the dog was retrieving its treat. The time taken by the dog at each attempt to find the smell was noted. The duration of time recorded was from when the dog returned to hoods to search for the sample to when it signed.

The entire process was also recorded on video. The following conclusions for each hood design was made by comparing the time taken to find the sample, observed behavior of the dogs and recorded footage.

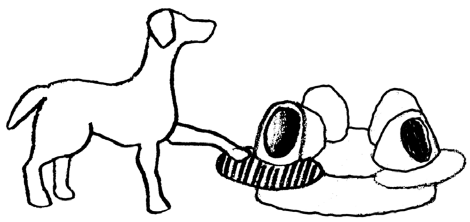
i) **Hood 1** – This was the tallest hood. The dogs consistently took the longest to find the smell sample under this hood. Also, the greatest number of false positives were signed for this design indicating a retention of the odor in the hood.

ii)**Hood 2** – The dogs could insert their snout deepest into this hood. Some dogs crouched while inserting their snout into this hood.

Figure 15. Kössi testing the hoods by Nose Knows (2018).

iii) **Hood 3** – The dogs could get their nose closest to the can in this hood. The angle allowed the dogs to get their snout close to the can. They found the smell can fastest under this hood. Ms. Paavilainen reported that when she tested with bigger dogs at the research facility, for some of the dogs, the edge of the hood aligned with the eye balls and there would be the danger of the edge pressing against their eyes.

The next iteration of the hood was designed with the opening to have a broad top like Hood 2 with the angle of Hood 3. The bottom edge was designed to be curved and not round to match the shape of a dog's snout (Figure 16). Reflecting on Resner's (2001) notes on design of interfaces discussed in Chapter 2, it is important to note that the dogs did not need to be trained to use the hoods. The design of the hoods were in line with the natural olfactory foraging tendencies of the dog and as an affordance, it did not present the dog with a challenge in the interface domain and enabled the dog to perform the task.



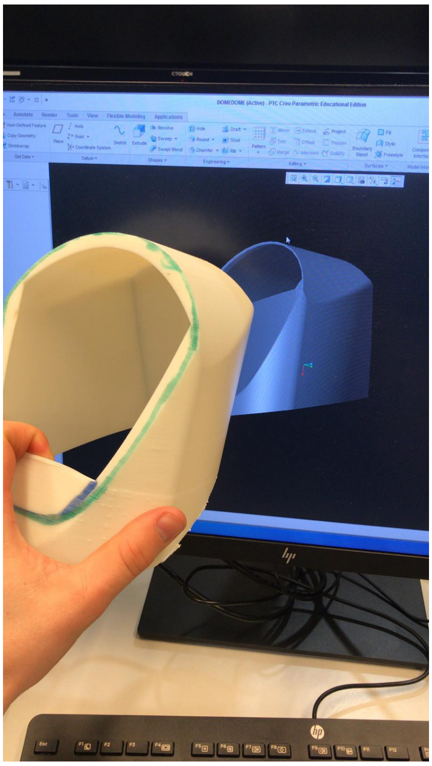


Figure 16. Design of hood being modified after testing by Nose Knows (2018).

5.1.4 The signaling mechanism

A crucial element of the scentBot was the interaction mechanism that the dog would use to signal upon finding the target odor. It would be ideal to be able to have the interaction mechanism based on honest signals, in context to the work by Mancini et al. (2015). While it would be ideal, it would be impractical to implement. Firstly, there isn't enough data available to devise algorithms to interpret honest signals for a wide range of scent samples. Secondly, these methods are better suited to be used with specific highly trained dogs who interact repeatedly with the system, where the system makes adjustments for each dog's behavior. For the design of a consumer product to be used with dogs of different sizes and training levels at home, a binary 'yes' or 'no' signaling mechanism would be appropriate. However, the signaling mechanism should be designed as close to an honest signal as possible, to reduce the cognition load on the dogs for using the machine.

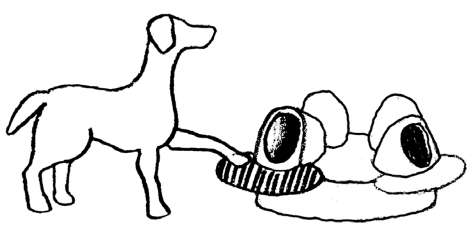
In nosework training, often the dogs are taught to sit or lay down in front of the correct sample. The dogs can be trained to express this gesture. From the interaction design perspective, perfect detection of this behavior could be achieved by using computer vision to detect the posture of the dog. This option needed the development of machine learning algorithms to accurately detect position of dogs of different breeds and was out of the scope of development for this thesis. Also, the accuracy of such a system could potentially decrease in home environments as noted by Hirskyj-Douglas et al. (2018) while reviewing the work of Mealin et al. (2016) done for recognizing dog postures using the Microsoft Kinect depth tracking. A simpler interface could be designed using infrared cameras near the bottom of the device, which would detect when the dog is sitting or lying in front of a sample. Building upon Resner's (2001) comment:

> It is not reasonable to expect them [animals] to have a sophisticated understanding of symbolism or iconography. For them, interfaces need to be as literal and direct as possible. Dogs cannot be expected to understand that pressing a button is the same as interacting with its owner. (p.19)

A dog cannot be expected to understand machine error or more abstract concepts like malfunctions in sensor sensitivity. This setup would not be free of machine errors and was not chosen as an interaction mechanism.

The team observed that a gesture that was often expressed by dogs during training carried out by the sponsors was pawing. Pawing is reported by many dog owners and the gesture can be defined as "rapid extension and flexion of a forepaw" (Bekoff, 1974). Dogs do this gesture towards an object, person or place of interest. Pawing would be close to a natural way of the dogs indicating their interest in a sample. For using the gesture of pawing as an interaction, it would have to be directed at a certain area of the machine. It is possible to record the pawing gesture using multiple sensors like touch, pressure, physical switches etc.

The FIDO project (Jackson et al., 2015) demonstrated the use of capacitive touch sensing by dogs using their mouth and nose.



A capacitive sensor could be used around the hood which detects the dog hitting that area with its paws upon finding the correct smell. While this would be the most intuitive interface, it could not be used due to accidental triggering by the dogs' fur or nose while sniffing the samples. Occasionally, quick taps made with dry or furry paws were not registered.

To avoid accidental triggering while searching for the smell, the interface would have to be placed slightly away while from the hood area while still clearly corresponding to the hood. A paddle in front of the hood would meet this criterion. The dog could be trained to paw in front of the hood. To test this, a cardboard prototype of the device with four 3-D printed hoods was made. Ms. Paavilainen was training the dogs to see if the lever like paddle switch was a viable interaction mechanism. Initially, the paddle area was the same color of cardboard as the rest of the body. This was corrected in the initial stage of the training by using markers to color them black (Figure 17).

Figure 17. Cardboard prototype of scentBot by Nose Knows (2018).

The process followed for testing the interface is as below:

i) Familiarizing the dogs to the smell of eucalyptus, which was the target odor. The dog was presented with the target odor in a can and was rewarded when it smelled it.

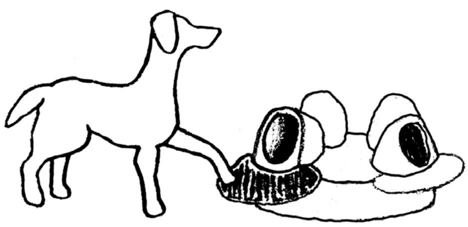
ii) The can containing the target odor was kept on the floor and the dog was rewarded when it would come smell it and paw next to the can.

iii) The can was kept under one of the hoods and the dog had to find it and paw close to the hood to get the reward.

iv)The can was kept under one of the hoods and the dog had to find it and paw the paddle to get the reward.

None of the dogs could complete Step iv of the task. This meant that either the interface would not work or there was a failure in communication of what the task was. The dogs were pawing, but they repeatedly pawed areas right next to the can inside the hood, instead of the paddle (Figure 18).

Figure 18. Nala pawing inside the hood by Nose Knows (2018).



The test tasks were modified to communicate the signing task better.

i) The search for the target odor was removed.

ii) A post-it note was placed on the floor and Ms. Paavilainen would touch it. When the dog brought its paw to the post-it note it would be rewarded.

iii) The treat was given at a distance from the post-it note and when the dog returned after eating the treat, the place of the post-it note had been changed. When the dog touched the post-it note with its paw, it was rewarded (Figure 19).

iv) In every successive round of training, the post-it note was gradually brought near the prototype until it was finally placed on the paddle of the prototype.

Figure 19. Lyra pawing on post-it note by Nose Knows (2018).

This method helped to communicate the task to the dog and in the same training session, they learned to use the paddle switches (Figure 20).

Due to a high viability of this interaction method, it was implemented in the final design. The sponsor took the cardboard prototype to the sponsors' research facility to test with more dogs. Their feedback

(Figure 21) was that the paddles should be made bigger to stand out more as dogs with bigger paws often hit the edge of the paddle and not the paddle. The paddle size and width was changed for the final design.

Figure 20. Nala using the paddle switch prototype by Nose Knows (2018).

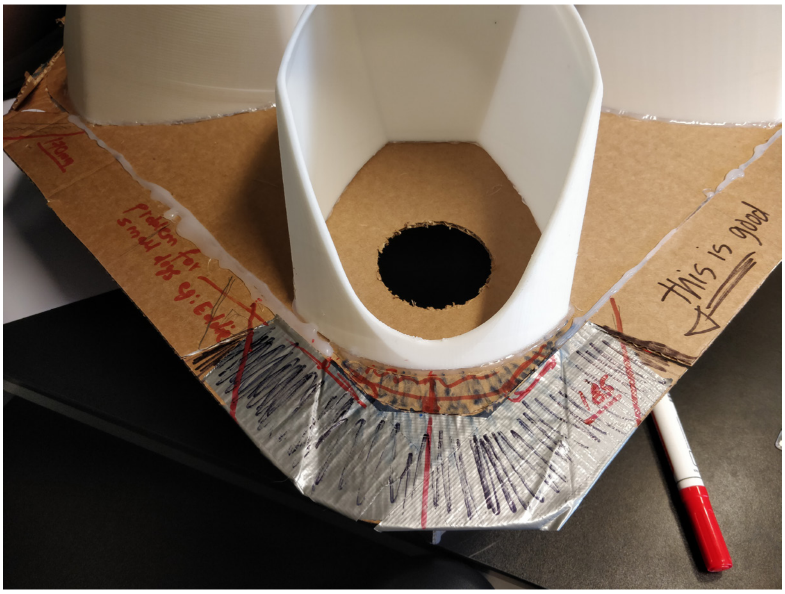
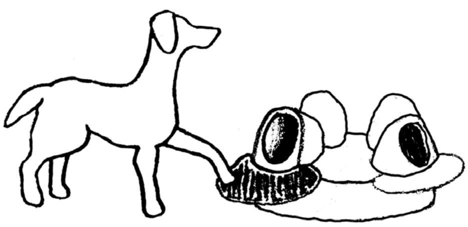


Figure 21. Cardboard prototype with sponsor's feedback by Nose Knows (2018).



5.1.5 Design of the scentBot casing and choice of materials

In line with SR2, the device had to be stable and not tip over even with aggressive pawing. In the survey conducted (Appendix 1), pet owners indicated a clear preference for square devices with rounded corners (47.9%) and for circular devices (42.9%) (Figure 22).

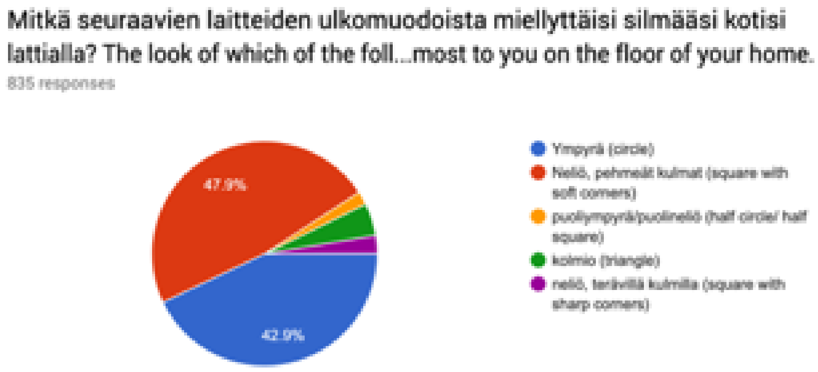


Figure 22. Pie chart showing distribution of preferences of the shape for an electronic device kept on the floor. From "Survey of your dog and you" by Nose Knows, 2018.

The paddle interface was easier to communicate to the dogs when arranged in four corners of the square and this was the deciding factor for the shape of the device. This also allowed enough room for the electronics and 16 cans with smell samples to be placed inside the machine. The prototype of the device was 3-D printed using selective laser sintering (SLS) and in house 3-D printers. For commercial production, injection molding of the parts is possible. Figure 23 shows the exploded view of the device.
There has been no report of physical damage to the device while being tested with the dogs since May 2019.

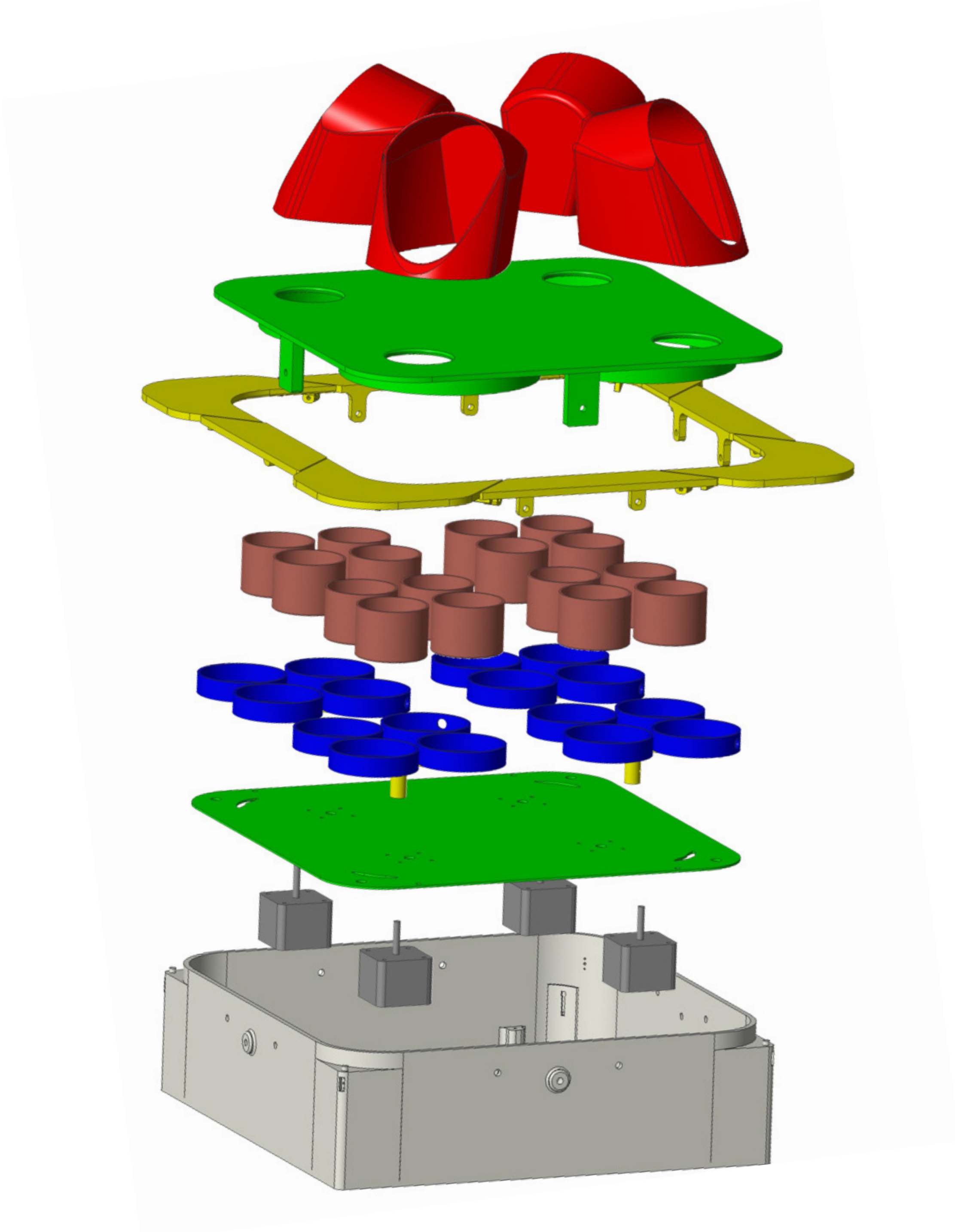
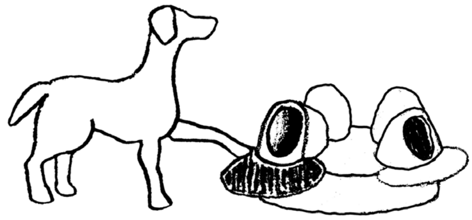


Figure 23. Exploded view of scentBot by Nose Knows (2019).



5.1.6 Mechanism and electronics

The four hoods are attached to a removable top plate (Figure 24). This needs to be removed to load samples in. Under each hood, there is an array of four can holders for placing the scent cans. The can holders are mounted on a motor in a way such that it is possible to align only one scent can with the hole in the hood.

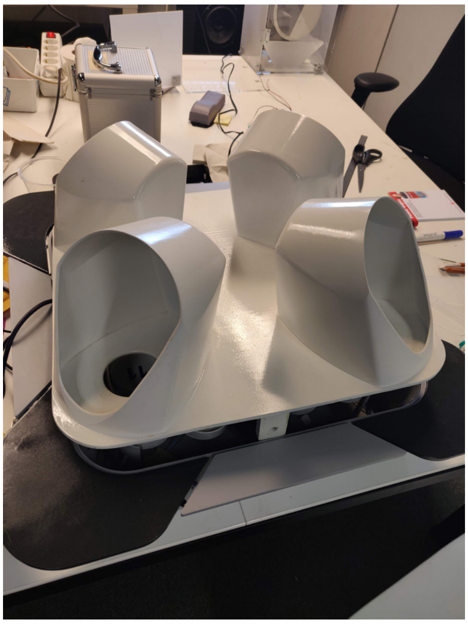


Figure 24. scentBot with partially open lid by Nose Knows (2019).

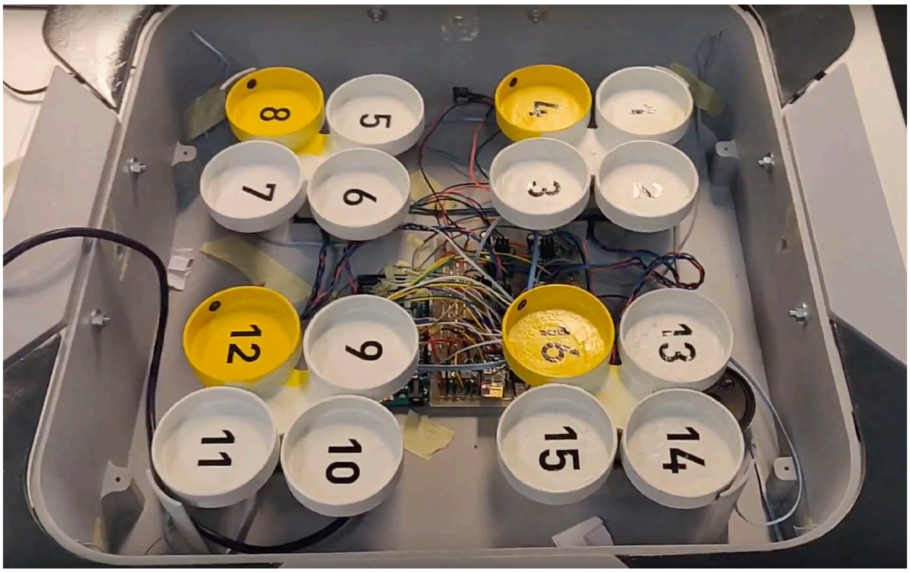


Figure 25. Inside the scentBot by Nose Knows (2019).

The total number of can holders is 16, grouped into 4 arrays of 4 holders each. As seen in the image (Figure 25) each array has a holder marked yellow for placing the target holder into (Number 4, 8, 12 and 16 in Figure 25). With the 16 sample holders presenting themselves in sets of four, it is possible to have over 1600 combinations. The scentBot algorithm limits this with the condition that after each shuffle, there has to be one and only one correct smell sample showing up under any one hood. The computation is handled by an Arduino based board and an ESP module.

After the PDP project, a printed circuit board was made for the electronics (Figure 26).

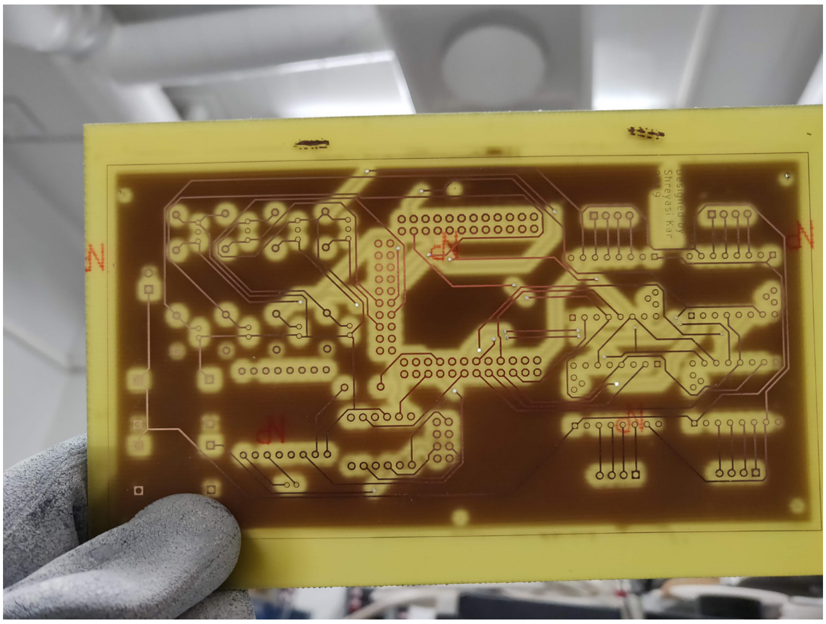
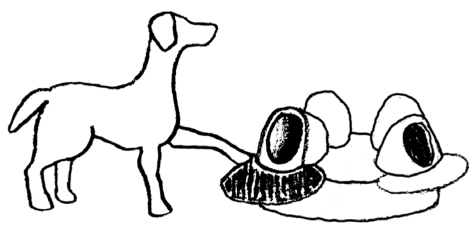


Figure 26. Printed circuit board for scentBot by Nose Academy (2019).

Initially, it was planned that the treatDispenser would be producing the clicking sound. In clicker training, it is crucial that the click sound be given as a reward as soon as the desired task is completed (DR4). Keeping this in mind, a sound module which would play the clicker sound was added to the Arduino in the scentBot. Along with the clicker sound, two new sounds were added. First is a chime that plays when the shuffling algorithm completes and a new puzzle is presented to the dog. The second is a shutdown tone. Similar to Resner's (2001, p 63) findings in Rover@Home, the dogs soon started to associate the sound of the motor of the treatDispenser as a reward sound.

The scentBot runs on 12V DC which is getting converted from the mains line at the wall using a wall wart style adapter (DR2).



5.2 Designing the treatDispenser

The design of the treat dispenser followed a user-centric iterative process. There were three dog-centric design guidelines for the treatDispenser. Firstly, it should not jam since it is meant to be used independently by the dogs while their owners are away. Secondly, there has to be a controlled number of treats dispensed, ideally one treat at a time, in the interest of the health of the dog. Thirdly, due to the strong odor of dog food, this had to be a separate device from the scentBot. At this point it is also pertinent to understand the motivations of the pet owner and how they would typically use the device.

Some of the commercially available treat dispensers were tested with a variety of treats. Based on what their dogs like to eat, users put in a variety of treats into the treat dispenser. One of the primary reasons for treat dispensers jamming is that users put irregularly shaped treats into the machine. The second reason was that the dog food (and cat food) have a lot of small powdery particles that become sticky resulting in clumps of treats. This would happen especially if the treats were left out for a few days. Occasionally the dog food stored in the treat dispenser would swell up after absorbing moisture from the air and clog the dispenser. Deconstructing the treat dispensers gave a better insight into the mechanism used to dispense the treats.

There was a total of six iterations made in the process of designing the treatDispenser (Figure 27).

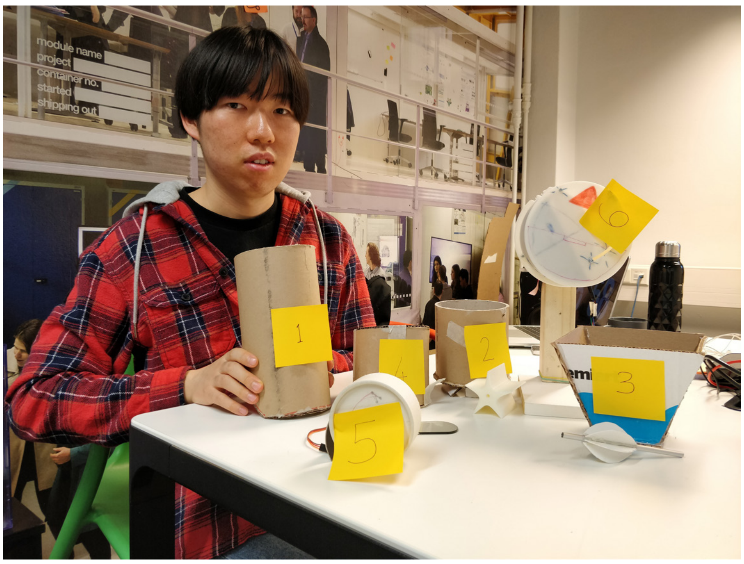


Figure 27. Six iterations of the treatDispenser by Nose Knows (2019).

5.2.1 Iteration 1

For the first iteration, a feeder-hopper mechanism was attempted. The tank with the treats was vibrated with pager vibrator motors while a servo motor controlled the opening and closing of a gate at the tapered bottom end of the tank. The gate did get stuck and it was very difficult to control the number of treats falling down. A second gate would be needed to reduce the number of treats coming out. This design was abandoned.

5.2.2 Iteration 2

A cylindrical container with a rectangular hole at the bottom held the treats. A wheel with a star cross section fit into the rectangular hole. This would rotate and with each rotation, carry some treats down (Figure 28).

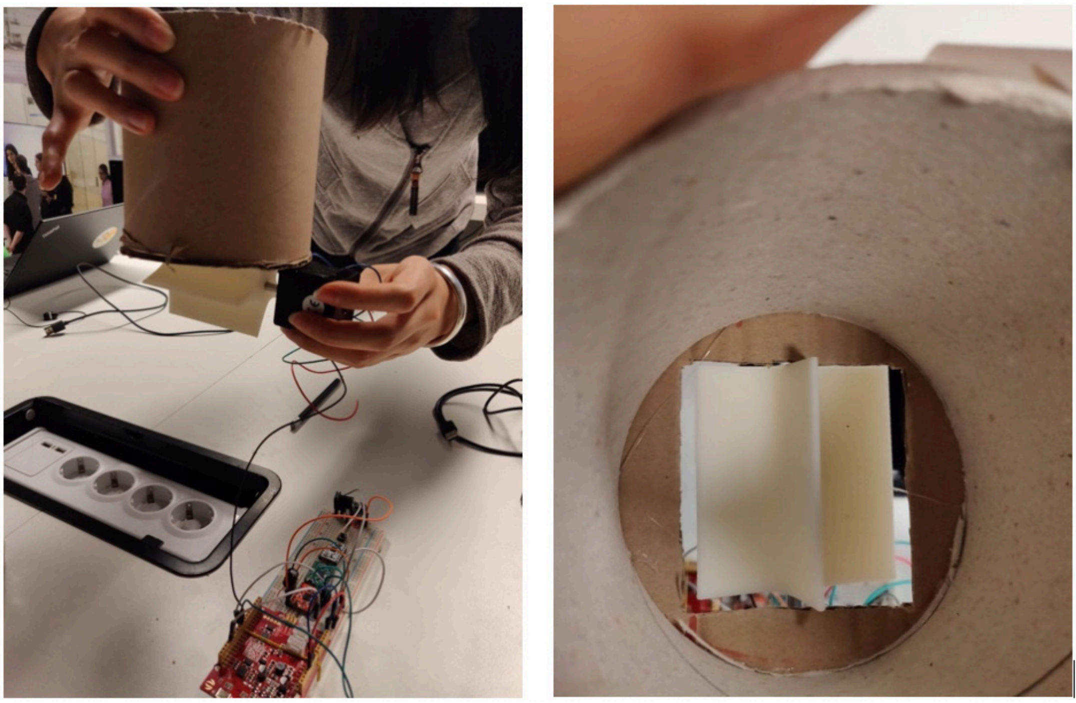
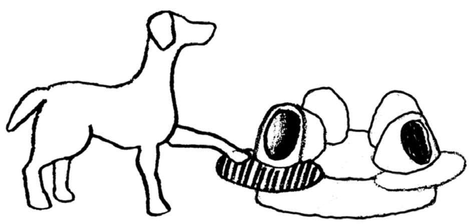


Figure 28. Iteration 2 of treatDispenser by Nose Academy (2018).

The star wheel was long and it carried a lot of treats down. Also, in between rotations, the treats would slide down from the gap between the wheel and the rectangular opening. Two flexible flaps



could be used to solve this problem. It was also possible to reduce the length of the wheel and change its shape to carry fewer treats. This design option was viable and developed further.

5.2.3 Iteration 3

The cylindrical container was replaced with an inverted pyramid to slide the treats downwards towards the opening. A smaller elliptical wheel controlled the dispersal of the treats (Figure 29). Compared to iteration 2, this dispensed fewer treats but it was unpredictable and occasionally would dispense several treats and the wheel would get stuck. Iteration 4 built upon iteration 3 by introducing a second chamber under the wheel to control the number of treats falling down. This still did not solve the issues of iteration 3. After this iteration, this design approach was abandoned.

Figure 29. Iteration 3 of treatDispenser by Nose Knows (2018).

Figure 30. Resun AF-2005D Automatic Aquarium Fish Feeder – Nature Aquatics Online Shop, (n.d.) [digital image]. Retrieved from https://nature-aquatics.com/shop/product/resun-af-2005d-automatic-aquarium-fish-feeder/.

Failure to design a treat dispenser to meet all the design criteria lead to broadening the search for devices that dispense food. Two dispensers which stood out were gum ball style candy dispensers and automatic aquarium fish feeders. The gum ball dispenser worked with uniformly shaped smooth units of candy. This would rarely be the case with dog treats so the focus was narrowed to the aquarium fish food dispensers (Figure 30). This was especially interesting as they work with dry food in extremely humid environments.

5.2.4 Iteration 5

This cardboard prototype was adapted from the mechanism of a fish food dispenser. The treats were placed in a cylindrical chamber which was mounted on a motor. The chamber was mounted in a way such that at all times, stationary and during rotation, the curved surface of the cylinder was tangential to the ground. An adjustable flap running along the curved wall of the cylinder would trap a few treats in it during each rotation. A small section of the curved wall of the cylinder at the end of the flap would open during rotation due to gravity and deposit the treats. The width of the flap was adjustable according to the size of the treats. During testing, this prototype continuously dispensed three to four treats and was developed further in the next iteration.

5.2.5 Iteration 6

This iteration was a scaled-up 3-D printed model of iteration 5. In addition to being scaled up and more durable, it also introduced a slot for additional gates to be placed in order to control the number of treats being dispensed. These gates were rectangular pieces of acrylic with laser cut holes of different shapes and dimensions (Figure 31).

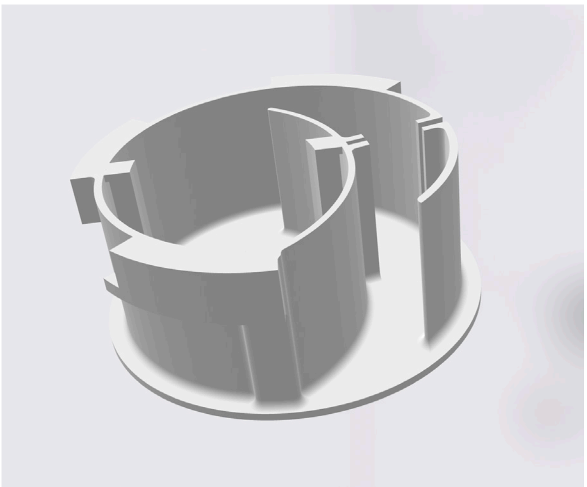
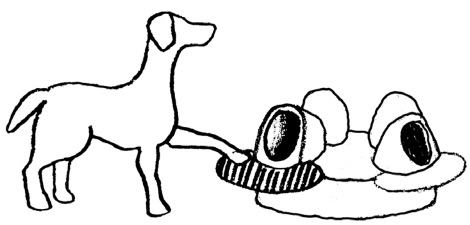


Figure 31. treatDispenser 3-D model by Nose Knows (2019).



From iteration 6, the final prototype introduced a small removable tray for easy refilling of the treat dispenser (figure 32). This tray was designed to be small to limit the size and number of treats the user can put into the treatDispenser.

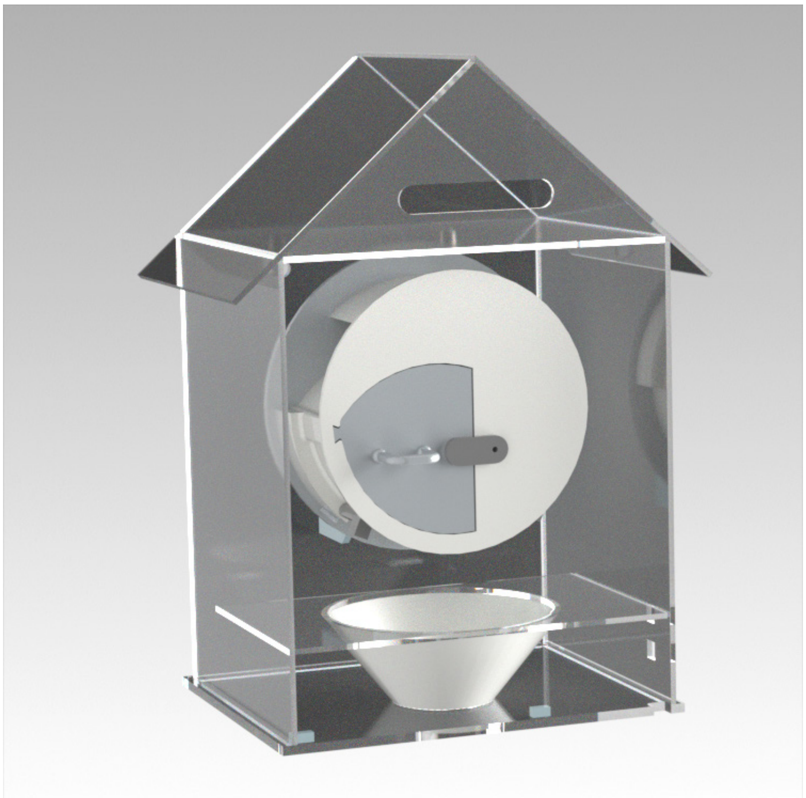


Figure 32. 3-D model of final treatDispenser prototype by Nose Knows (2019).

5.2.6 Electronics of treatDispenser

The treat dispenser is running on the Adafruit HUZZAH feather board with an ESP8266 microcontroller. The motor uses the same silent step sticks as the scentBot.

The prototype created in May 2019 had an additional triangular housing on the top to accommodate a webcam, microphone and speakers to enable the pet owner to see the training and have the possibility of remote communication with their dog. The webcam set up was replaced by an internet protocol (IP) camera that the user can choose to place in a place of their choice independent of the placement of the treat dispenser. The IP camera also has the possibility of two-way audio communication.

Initially, the treatDispenser was also designed to be mounted lower and have a touch screen interface for the dog to be able to see their owner during a video call and maybe even call them. This feature was dropped during the iteration process.

5.3 Designing the mobile application

The mobile application (app) serves three main functions

i) To have a remote control of the system
ii) To track the training
iii) To be a training aide

A fourth feature that was initially planned out but not designed as of yet is a social network to connect users using the device.

The app design was done by the students at Yonsei University and developed externally in Finland.

Figure 33 below shows the initial wireframe of the app.

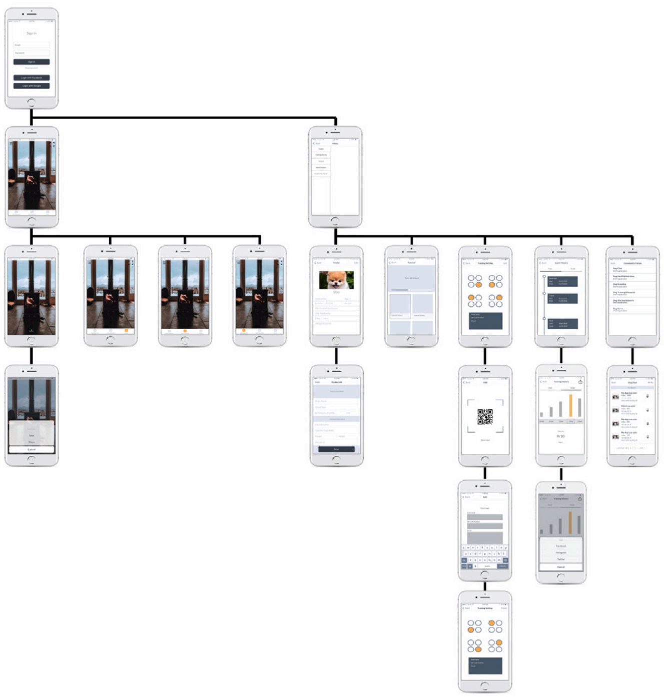
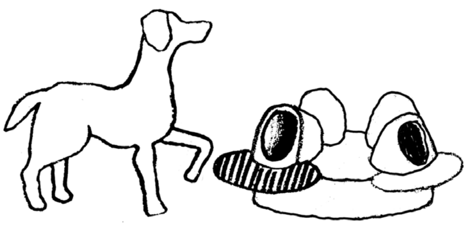


Figure 33. Wire frame of application by Nose Knows (2019).



The app has training videos to guide the human user through the steps of training. During the training, the human user can use the clicker button in the app which produces the click sound and triggers the treatDispenser to give a treat. This button can also be used remotely to reward good behavior.

The user can use the app to log what smell samples were loaded into the machine. To make this process more efficient, the nosework scents come with a QR code which can be scanned in. As the training is completely customizable, it is also possible to type in each sample name. Once this data is entered, a schedule for when the scentBot should operate can be set. The app tracks the training of the dog and reports the progress made to the user. Using the IP camera, the human can see how the training is progressing remotely and communicate through audio with the dog. Figure 34 shows some of the screenshots of the app.

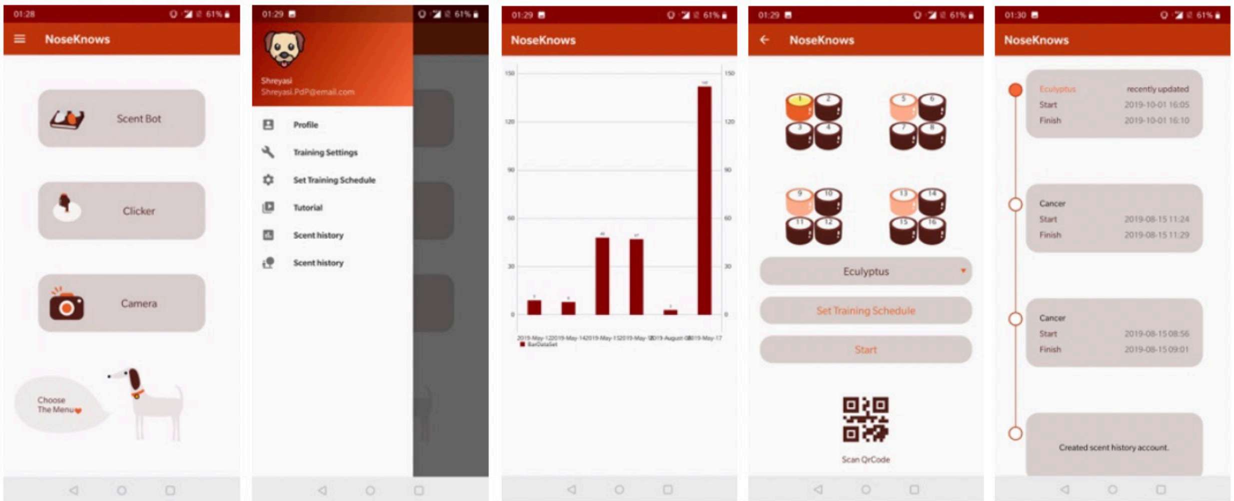
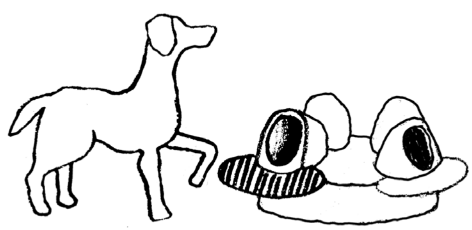


Figure 34. Screenshots of app by Nose Knows (2019).

Chapter 6

Suggestions for future development of Scent Bot

Based on the user tests, following chapter suggests some of the changes that can be made to the design of Scent Bot.



The following changes can be implemented in the device for future development.

i) Similar to the auditory cues of clicking, new puzzle and shut down, visual cues with lights can be implemented in the device for deaf dogs.

ii) A mesh under the hole of the hood should be placed to prevent the dogs from putting their nose or paws on the smell sample. If too much pressure is applied, it can change the alignment of the motors and hamper the accuracy of the machine.

iii) Softer springs can be placed under the paddles for smaller dogs

iv) If the signaling mechanism can be placed closer to the hood and increased in sensitivity, the training required for the dog to use the machine will be reduced.

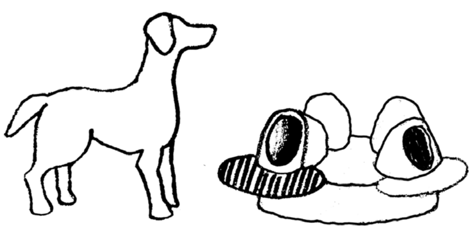
v) The paddles can have covers in different colors with different textures to suit individual dogs' sensitivities.

vi) When the dog is left alone with the machine, a scent can be placed outside of the machine with the smell that the dog is being trained to recognize. This can serve as a memory aid for the dog and reinforce the training.

Chapter 7

Discussion

This chapter evaluates and discusses the relevance of the thesis.



Through an extensive literature review and market research, it was found that Scent Bot will be the first olfactory enrichment interactive device available for pet dogs. While reducing separation anxiety and providing entertainment for dogs in confinement of homes, the Scent Bot trains dogs to develop a sharper sense of smell. It can improve the behavior of the dog. Calmer, occupied dogs are less likely to display destructive behavior at home when alone. The device can potentially enhance the pet-human bond in many ways. It can reduce the anxiety and stress of dog owners knowing that their dogs are occupied and receiving mental stimulation while they are away. Training to use the Scent Bot is a training for both the humans and the pet dogs. The human is taught how to communicate with the dog and pay attention to what they are doing as well as take keener interest in their pet. Väätäjä et al. (2018), conducted studies with Finnish and international dog owners “to capture the motivations for using dog activity trackers, their utility, user experience, gained insights, and impacts of use.” (p. 1). The studies found that “the owners were motivated to change their behavior in respect to the dog based on the insights gained from activity tracking. The tracker inspired the owners to spend more time with the dog and to be more observant to its behavior” (p. 10).

Humans can train the dogs to find any scent they are interested in and develop a hobby together such as mushroom hunting. Potentially this can even create part-time jobs for dogs by training them for on-demand nosework. For instance, in Finland, a company called Jobs For Dogs uses pet dogs trained in nosework for “Human ID Scent Tracking” when needed. Similarly, high performing dogs can be recognized and further trained for specialized olfaction jobs.

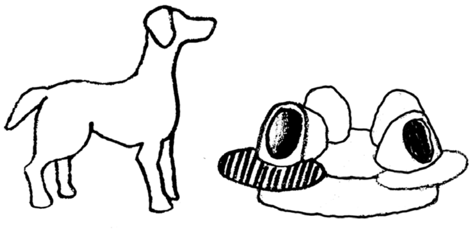
Although developed as a consumer product, the Scent Bot can be used for research and professional training of any type of dog working with olfaction like K9 units, drug detection dogs, medical detection dogs etc. The product lies at the intersection of research applications and consumer use.

The topic of dog olfaction capabilities is very current and has been the topic of several studies in the last few years. In June 2019, Edwards reported an automated canine scent-detection apparatus, designed bringing back samples collected from the field for evaluation by multiple dogs in a laboratory. Canine olfaction has been the topic of over 20 published research papers in 2019 alone. An area of special interest within this research has been the detection of diseases by dogs.

Humans are realizing the potential of a new kind of A.I., Animal Intelligence and not Artificial Intelligence. As an example, Slovenian artist Maja Smrekar introduces in her work !brute_force, the concept of co-programming, where neural networks are programmed by dogs (!"Brute_force," n.d.). Another example of A.I. are pigeons trained to distinguish between benign and malignant human breast histopathology did so with the accuracy rate between 87 to 90 % which is the same as that of highly trained radiologists and pathologists (Levenson et al. 2015). Like dogs, the pigeons also work for food. While the idea of having animals providing breakthroughs in technology is exciting, it can take years for it to become viable. The efforts of researchers can be augmented through devices such as those built by Mancini et al. (2015), Edwards (2019) and, the Scent Bot.

Several research papers raise concerns about the challenges in designing for a non-human user and agile design methods are suggested to overcome those challenges (van der Linden et al. 2019 ; Ritvo & Allison, 2017; Lehtonen, 2013). The Scent Bot uses a similar design process to that suggested in the research van der Linden et al. (2019). It was designed by an interspecies, interdisciplinary team consisting of dogs, their owners, a dog trainer, a veterinarian, an interaction designer, engineers and marketers. The rapid prototyping, and continuous testing of the prototypes contributed positively towards the usability of the device. There is a lot more to be discovered in how animals can be involved in the design process and their increased involvement will certainly benefit the field of ACI.

The iterative participatory design process followed during the development of Scent Bot contributes and expands the conversation in ACI about inclusion of animals while designing for them. There are many different ways in which participants can participate in a participatory design process. Hirskyj-Douglas & Lucero (2019) discuss the different approaches taken by Mancini & Lehtonen (2018), Hirskyj-Douglas et al.(2015), Wasterlaken & Gualeni (2016) and,



Lawson et al.(2016) to involve dogs in their design process. They note:

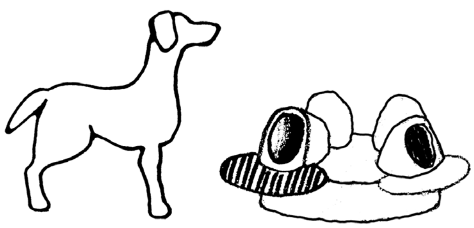
> All these models on participation however share the same challenge of including the dog end-user as a stakeholder just varying on levels of representation, interpretation and contribution. Thus, this is a procedure of mitigation as allowing the animal to decide upon the properties and affordances in the process can be ambiguous and unregulated. . . . As such, there are clear challenges within DCI [dog computer interaction] towards both how the dog interacts and has productive power within the design process through participation. (p. 3)

Design terminology such as participatory design is vocabulary that comes from design processes involving a single species, humans. With non-human animals being involved in the design process, maybe there is also a need for evolution of an interspecies design vocabulary to better report and acknowledge their participation.

Chapter 8

Conclusion

This chapter reiterates the most relevant points of the thesis. A video link to see the Scent Bot in use can be found at the end of this chapter.



Dogs and humans have evolved together and developed unique interspecies communication between them. Dogs, being highly trainable, have been tasked with jobs for centuries. The majority of these jobs rely on the dogs highly specialized sense of smell. Humans are researching the ability of dogs to detect cancer and other diseases by smelling biological samples. However, in this research, there is a need for animal-computer interfaces to eliminate human error and allow dogs to signal more intuitively in order to reinforce the training.

The number of people having dogs as pets is on the rise but the majority of the pet dogs spend a significant amount of time alone at home in confinement during work days. With a plethora of furniture, accessories, toys and gadgets available for pet dogs, humans are spending more on their dogs than they have before and a particular sector that is seeing a booming growth is that of pet technology. Some of the broad categories of available pet technology are wearables, feeders, communication devices, toys and enrichment devices. Most of the toys and enrichment devices designed for dogs rely on the dog's sight. Dogs primarily use their sense of smell to navigate their environment.

Researchers and trainers working with dogs practicing nosework or other odor detection tasks report that the dogs get calmer while using their sense of smell and it is a very engaging activity for them. Scent Bot is the first of its kind interactive enrichment device ecosystem for pet dogs that is designed for their sense of smell and makes use of their olfactory foraging instincts. Scent bot can be used by the dogs independently and provides them with mental stimulation while they are alone at home.

Scent Bot improves the pet-human bond as they initially work together and learn the basics of nosework. Through a series of exercises, the human indicates to the dog what smell the dog should try to find. The device ecosystem consists of three parts, scentBot, treatDispenser and app. The scentBot contains 16 smell samples inside it. It presents the dog with four samples of smell, from which it should find the target odor that it is being trained to detect. When it finds the target odor, it taps the paddle in front of the hood under which the target odor appeared. If it was correct, the scentBot confirms this with the clicker sound and the treatDispenser which is mounted at a distance rewards the dog with a treat. By the time the dog returns to the scentBot, it is presented with a new smell puzzle to solve. The human user has control of the schedule and complexity of the training through the mobile app. The app acts as a remote control for the whole system. It is connected to a camera which allows the human to see the dog while training and has capability of two-way audio. The app tracks the progress of the dog, records what scents the dog is being trained for and provides tutorials on training.

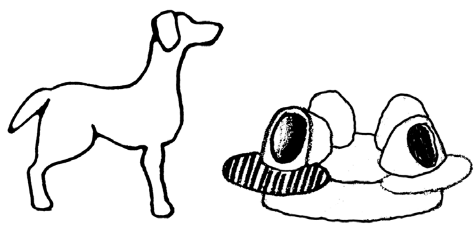
While being designed as a home enrichment device, Scent Bot can be used in in any professional or research setting where dogs are being trained to use their sense of smell for different tasks.

To conclude, the Scent Bot was designed with dogs and the design process was informed by current conversations in animal computer interaction. It forwards the conversation by demonstrating the use of a looping, iterative participatory design process with animals to develop technology to be used by them in a real-world product development scenario.

Video link - https://vimeo.com/366656814

Password - scentBot

This thesis can be used as a flip book from the bottom right corner to understand the interaction mechanism of the scentBot.



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